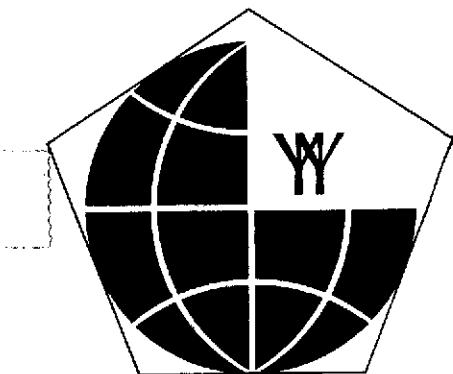


# **Suspended Particulate Size Distribution and Epidemiology of Respiratory Diseases in Houston**

**Prepared by  
C.T. Chen, Ph.D., M.P.H.**



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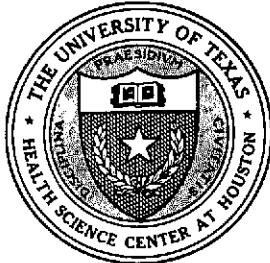
**Prepared by**

**C. T. CHEN, Ph.D., M.P.H.**

**Chief Investigator**

**The University of Texas at Houston**

**School of Public Health**



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## ABSTRACT

Numbers of respirable particulates per cubic meter of air measured under representative conditions in Houston for the year 1972-1973 were examined for correlation to existing respiratory disease data for Houston. The suspended particle size distribution was measured with the Royco Model 225 particle counter at fourteen sampling stations in the Houston area during a 7-hour period of the day in August, November, 1972 and February, 1973. The mass concentration data of suspended particulate matter was also collected by using the high volume sampler. The mortality data of respiratory diseases in Houston was compiled from the "Deaths by Age Group, Houston in 1970, 1971, and 1972. The isopleth maps of suspended particulate size distribution and mass concentration, and respiratory diseases were obtained by using the SYMAP computer program.

The regression analysis has been applied to the suspended particulate size distribution data measured. The validity of applying the power law to the suspended particulate size distribution was proved experimentally. Furthermore, the intercept ( $\log N_o$ ), slope (-m), and the percentage of particles in 0.3-0.7  $\mu\text{m}$  size range characterize the four stations which represent commercial, semi-rural residential, and industrial areas in Houston, and mark the seasonal variation as well.

For analyzing the meteorological influences on the suspended particulate matter, it could now be concluded that the isopleth maps of size and mass distributions of suspended particulate matter were essentially the same when the wind speed was 5 or less knots, and each distribution changed differently when the wind speed increased to more than 5 knots.

The suspended particulate size distributions associated more closely

than the suspended particulate mass concentration to the sum of mortality for asthma, bronchitis, and emphysema which was not affected by the socio-economic status. The mortality of pneumonia in Houston was better linked to socio-economic status than the suspended particulate size and mass distributions. The high tuberculosis prevalence was most observed in low socio-economic status areas. The high pollution level of suspended particulates might well aggravate the situation. The tuberculosis mortality rate had no significant association with socio-economic indicators but was worst in the area where the suspended particulate pollution was also high.

An expanded and detailed study in the Houston area and other areas over a long period of time is suggested in order to confirm and better define these findings.

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## I. INTRODUCTION

Air pollution may be defined as any circumstance which adds to or subtracts from the usual constituents of air that may alter its physical or chemical properties sufficiently to be detected by occupants of the medium<sup>1</sup>. Pollutants are usually considered as only those substances added in such concentration and of such duration as are or may tend to be injurious to or to adversely affect human health or welfare, animal life, vegetation or property, or as to interfere with normal use and enjoyment of animal life, vegetation or property<sup>2</sup>. Almost any natural or artificial composition of matter capable or being airborne is a pollutant. They may occur as particulate matter, dust, fumes, gas, mist, smoke, vapor or odor, or any combination of these forms. Chemically, they may be sulfur compounds, organic compounds, nitrogen compounds, halogen compounds, radioactive compounds, and metals. Types of effects associated with air pollution may be classified as follows: visibility reduction; material damage; agricultural damage; physiological effects on man and domestic animals; and psychological effects.

Research studies have documented a strong relationship between all respiratory disease and air pollution<sup>3</sup>. It seems likely that 25 percent of all morbidity and mortality due to respiratory diseases could be saved by a 50 percent abatement in air pollution levels. Since the annual cost of respiratory diseases is \$4887 million, the amount saved by a 50 percent reduction in air pollution in major urban areas would be \$1222 million. Particulate matter within the respirable range,

between 0.8 to 1.6  $\mu\text{m}$  diameter, is responsible for most of the respiratory diseases caused by air pollution<sup>4</sup>. The size of particles plays an important role in determining the particle dynamics in the atmosphere<sup>5</sup> and in determining the site and effectiveness of depositions in the respiratory tract<sup>4</sup>. However, the studies on size distribution of particles have been ignored with reference to respiratory morbidity<sup>6</sup>. Amdur<sup>7</sup> and Clayton, Jr.<sup>8</sup>, have pointed out that both concentration of pollutants and particle size must be considered input for air quality criteria. The ambient air of Houston had noticeable quantities of iron, copper, zinc, and siliceous particulates by morphologic identification<sup>9</sup>. It appeared that the size distribution of particulates in the Houston air should be measured.

The suspended particle size distribution was measured in fourteen sampling stations in Houston area during a 7-hour period of the day with the Royco Model 225 Particle Counter. The isopleth maps of suspended particulate size and mass distribution in Houston area were obtained by using the SYMAP computer program<sup>10</sup>. The difference between isopleth maps of size and mass distribution, the difference among the isopleth maps of different size were discussed. The meteorological influence had been taken into consideration for the interpretation of isopleth maps. The regression analysis has been applied to the data from stations 2, 4, 8, and 16, which were chosen to represent commercial, semi-rural, residential and industrial areas, respectively. This was to ascertain the validity of the power law of suspended particle size distribution and characteristics of each area within Houston.

Finally the mortality data of respiratory diseases in Houston in 1970, 1971, and 1972 were collected and their conformant, maps were constructed by using the SYMAP computer program. The association/correlation between

the suspended particulate distributions (size and mass) and the geographical distribution of respiratory diseases was analyzed.

## II. SUSPENDED PARTICULATE MATTER IN HOUSTON<sup>11</sup>

The survey of the ambient air for suspended particulate matter in Houston was initiated on December 27, 1967. Twenty-four-hour samples were obtained with a high volume air sampler. The sampler consists of a blower unit which is attached to an adapter for holding a fiberglass filter, a flowmeter to measure the amount of air drawn through the filter and a timing device used for automatic start up and shut off of the unit. During the sampling period air is sucked through the fiberglass filter at a measured rate. The filter was weighed before and after sampling, the difference in weights being the amount of suspended particulate matter per total volume of air passed through the filter. The weight of these particles is expressed in micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ). The particles ordinarily collected are within the size range of 0.1 to 100 micrometers in diameter.

By analyzing the data of the first two months, seventeen sampling sites were located and the frequency of twenty-four-hour sampling was decided at eight times per month. The address and map of the seventeen sampling sites are shown in Table 1 and Figure 1 respectively. They were established on a best-guess basis in order to have the results as representative as possible of the quality of the ambient air in the city of Houston. The isopleths maps of the annual geometric mean of suspended particulate matter in Houston for 1970 and 1971 are shown in Figures 2 and 3 respectively. They revealed that the Downtown area and the Houston Ship Channel area are the major contributors to pollution in the city of Houston.

The particulate matter data collected in 1971 has been summarized and compared to previous data from 1969 and 1970 as shown in Table 2. This Table gives the percentage of samples taken that exceeded the 24-hour average

Table 1. HOUSTON CITY AIR POLLUTANT SAMPLING NETWORK

1971

Site	Address
2	811 N. San Jacinto
3	824 San Antonio
4	10343 Hartsook
5	11212 Cullen
6	3801 Cullen
7	1115 N. MacGregor
8	3838 Aberdeen
9	6902 Bellaire
10	3735 W. Alabama
11	4420 Bingle
12	10413 Fulton
13	7330 N. Wayside
14	Kress & Lyons
15	12759 Market
16	13349 Vicksburg
Pasadena (P 1)	Waller Street, Pasadena
Deer Park (DP1)	1301 Center, Deer Park

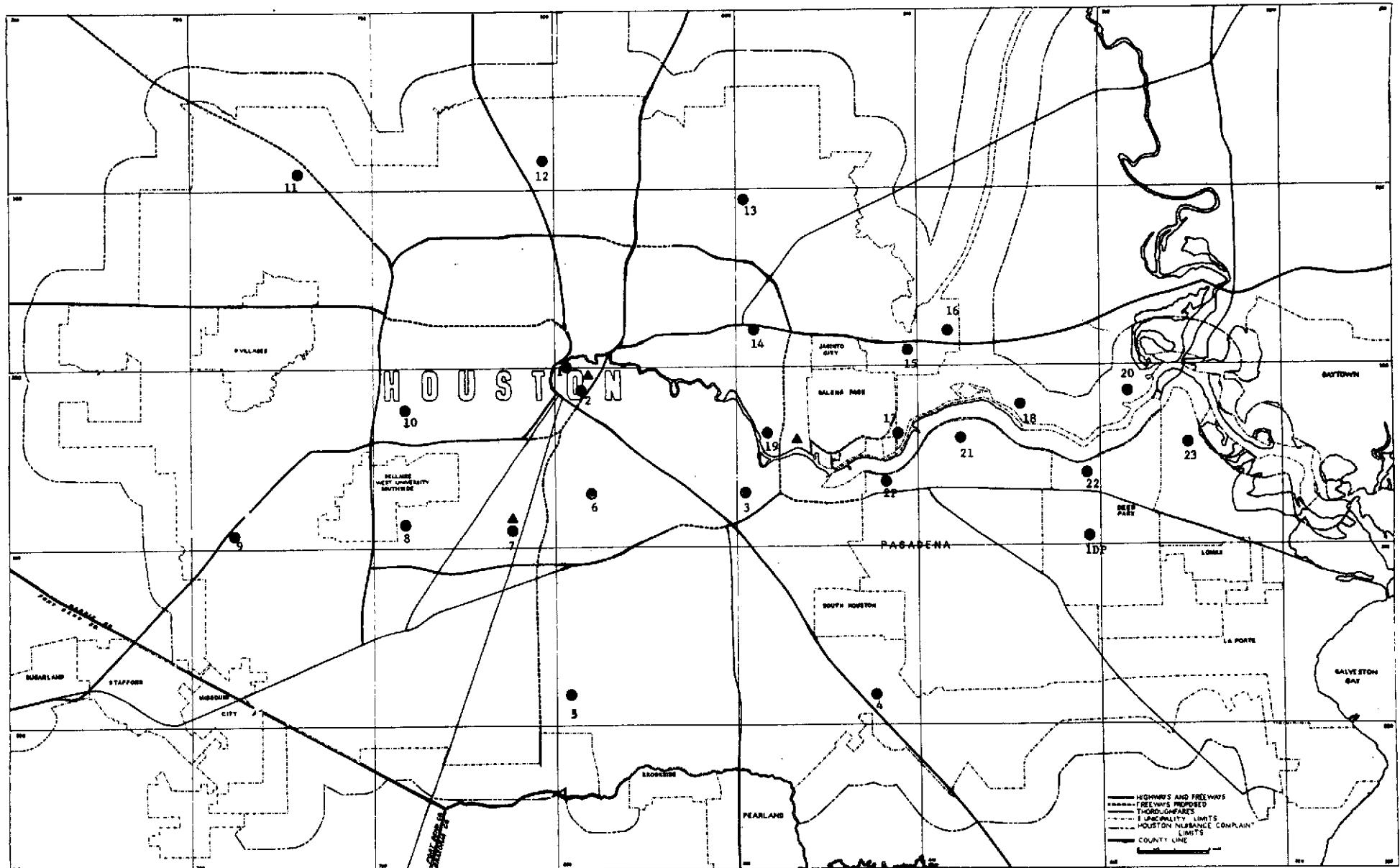


Figure 1. Suspended Particulate Matter Sampling Stations

- Permanent Air Sampling Site
- ▲ Mobile Air Sampling Sites

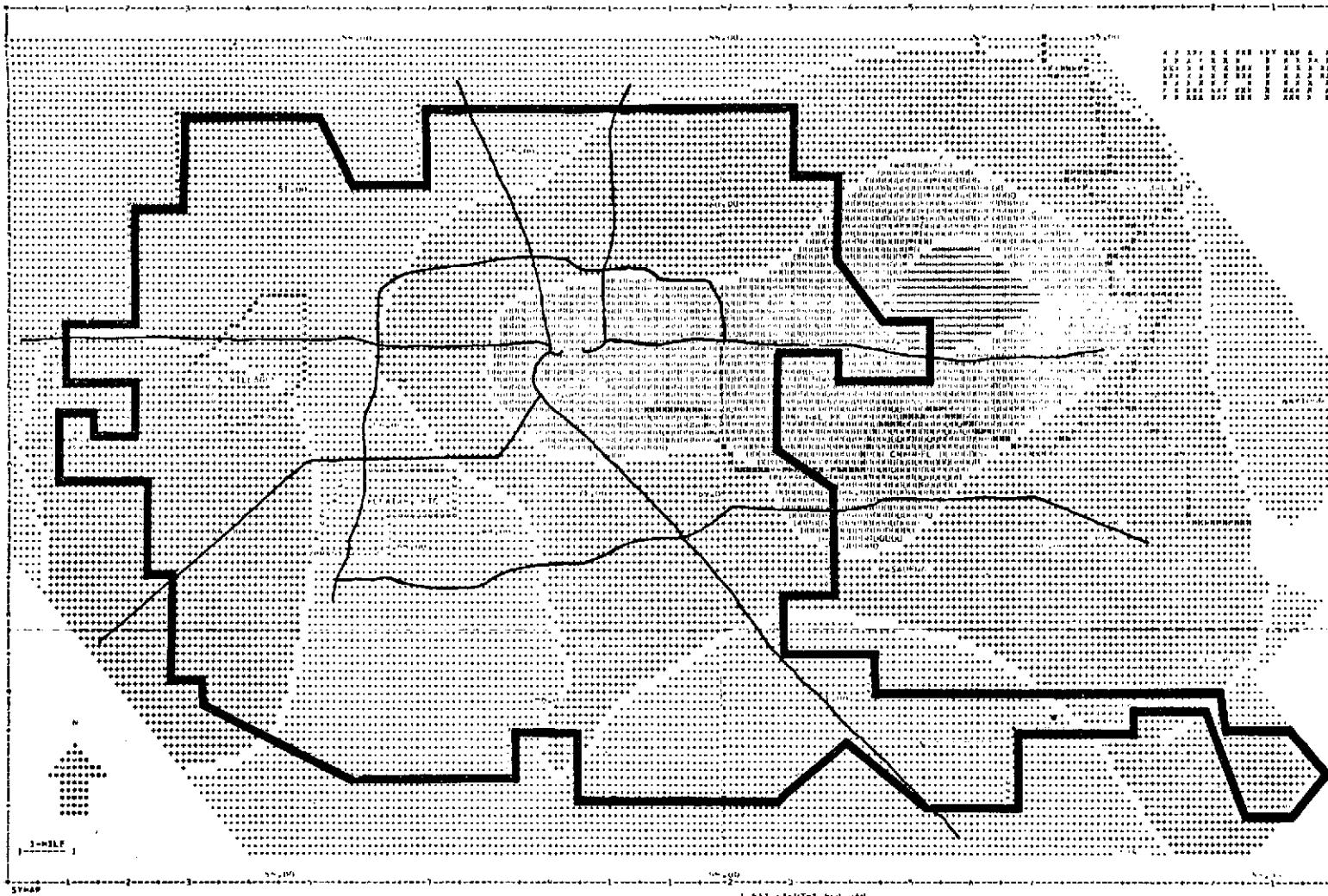


FIGURE 2.

Suspended Particulate Matter  
Annual Geometric Mean, 1970

This figure shows the long term geometric mean concentrations sampled during the year of 1970. As expected, a small cell of significant concentration appears immediately north of the ship channel. This is in complete agreement with the location of industrial sources and the predominant wind direction.

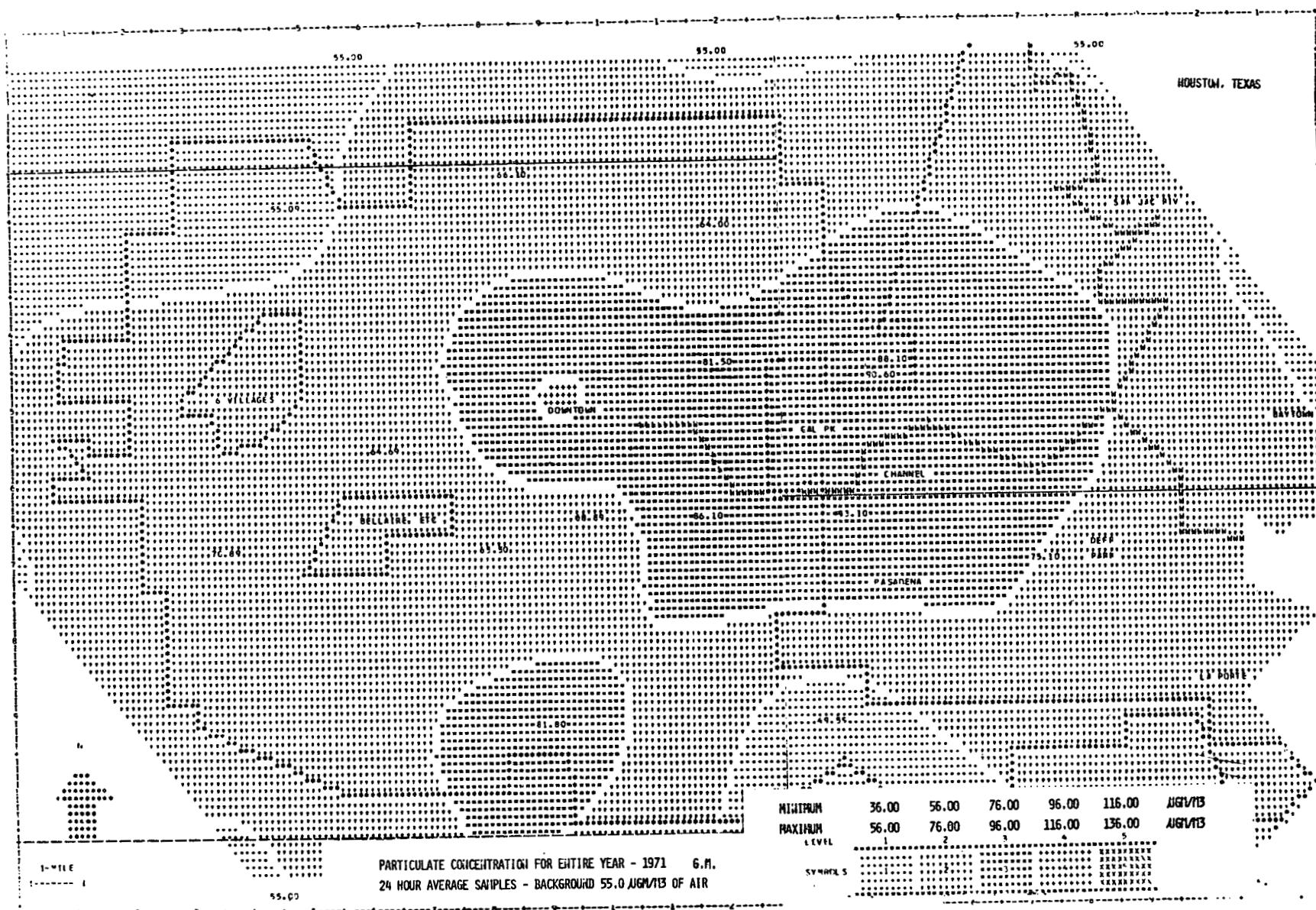


Figure 3. Suspended Particulate Matter, Annual Geometric Mean, 1971

Table 2. Ambient Air Data in Houston

	1969	1970	1971
EPA Standard 260 $\mu\text{g}/\text{m}^3$ 24 hr./ avg.	1.12%	0.22%	0.29%
TACB Standard 150 $\mu\text{g}/\text{m}^3$ 24 hr./ avg.	10.2%	4.8%	4.8%
EPA Standard 75 $\mu\text{g}/\text{m}^3$ 24 hr./ avg.	47.2%	29.4%	41.2%
TACB Standard 55 $\mu\text{g}/\text{m}^3$ Annual Geometric Mean	94.1%	70.6%	84.4%

This table gives the percentage of samples taken that exceeded the different 24-hour standards and the percentage of sites that exceeded the annual standards.

standards and percentage of sites that exceeded the annual standards. It indicated that the percentage of samples which exceeded the standard decreased from 1969 to 1970 but increased from 1970 to 1971. The percentage is lower in 1971 than in 1969. Overall, the pollution from suspended particulate matter in Houston improved over the three year period.

Although the rise of pollution from 1970 to 1971 cannot be attributed to any single factor, an increase in the automotive and construction activity was noted. Passenger car registration had an increase of 52,000 from 1970 to 1971 and the corresponding purchase of gasoline had an increase of 8.2%. The construction industry in 1971 had activities of \$607,869,917 with more than \$127,000,000 increase over the 1970 period.<sup>11</sup>

"Survey of the Composition of Particulates in Air Samples from the City of Houston" was carried out under the direction of Dr. Leslie Chambers of the School of Public Health, The University of Texas at Houston<sup>9</sup>. It was primarily to obtain a much more thorough description of the metallic composition of the suspended particulate matter sampled in Houston. The highest values for lead were found in the vicinity of Galena Park where both industrial and internal combustion sources exist. The distribution pattern of lead coincided with the heavy traffic patterns. The manganese concentrations were significantly higher in the heavy industrial areas. Manganese emissions are mainly caused by metal processing and fabrication industries. The level of copper was quite homogeneous throughout the city with indicated sources in the Houston Ship Channel, Bellaire and northwest areas. The levels of the following metals were found to be generally very low: zinc, cadmium, chromium, cobalt, lithium, nickel, magnesium, aluminum, vanadium, and tin.

No previous study of the particulate size distribution at various areas of Houston has been conducted. Because of the relationship between particle size diameter and site of deposition<sup>4</sup>, it appeared that the size distribution of suspended particulate matter in the Houston air should be measured.

### III. INSTRUMENTATION

In order to determine the suitable instrument and technique for this project, a testing of various instruments and techniques for particulate matter sampling was conducted. The instruments tested were: monitoring-filter holder, high volume air sampler, Anderson non-viable particle sampler, Millipore  $\pi$ MC particle measurement computer system, Coulter model 130 portable air pollution monitor, Royco model 220 particle counter, electrostatic sampler, Wild-20 optical microscope, Siemens Elmiskop I electron microscope, and ETEC 'Autoscan' scanning electron microscope.

#### A. Calibration of Rotor-flow meter

All particulate matter samplers need to have a specific constant air flow. Thus a reliable flow meter is necessary to set and check the flow rate of the instruments. The Rotor-flow meter of Gelman Instrument Company was calibrated against the Wet Test Meter of Precision Scientific Co. The calibration curves are shown in Figures 4 and 5.

#### B. Monitoring - Filter Holder

Millipore Type GS 0.22 $\mu$ m pore size filter paper (47 mm diameter) was placed on Gelman Model 1220 Monitoring-filter holder to collect suspended particulate matter for 1, 2 and 4 hours at the flow rate of 5 lpm. The filter paper was made transparent by an application of oil and transferred to the stage in a wild-20 optical microscope. Because multi-layers of particles were deposited on the surface of the filter paper, resolution of individual particles proved almost impossible. Therefore the monitoring-filter holder could not be used for sizing and counting of suspended particulate matter.

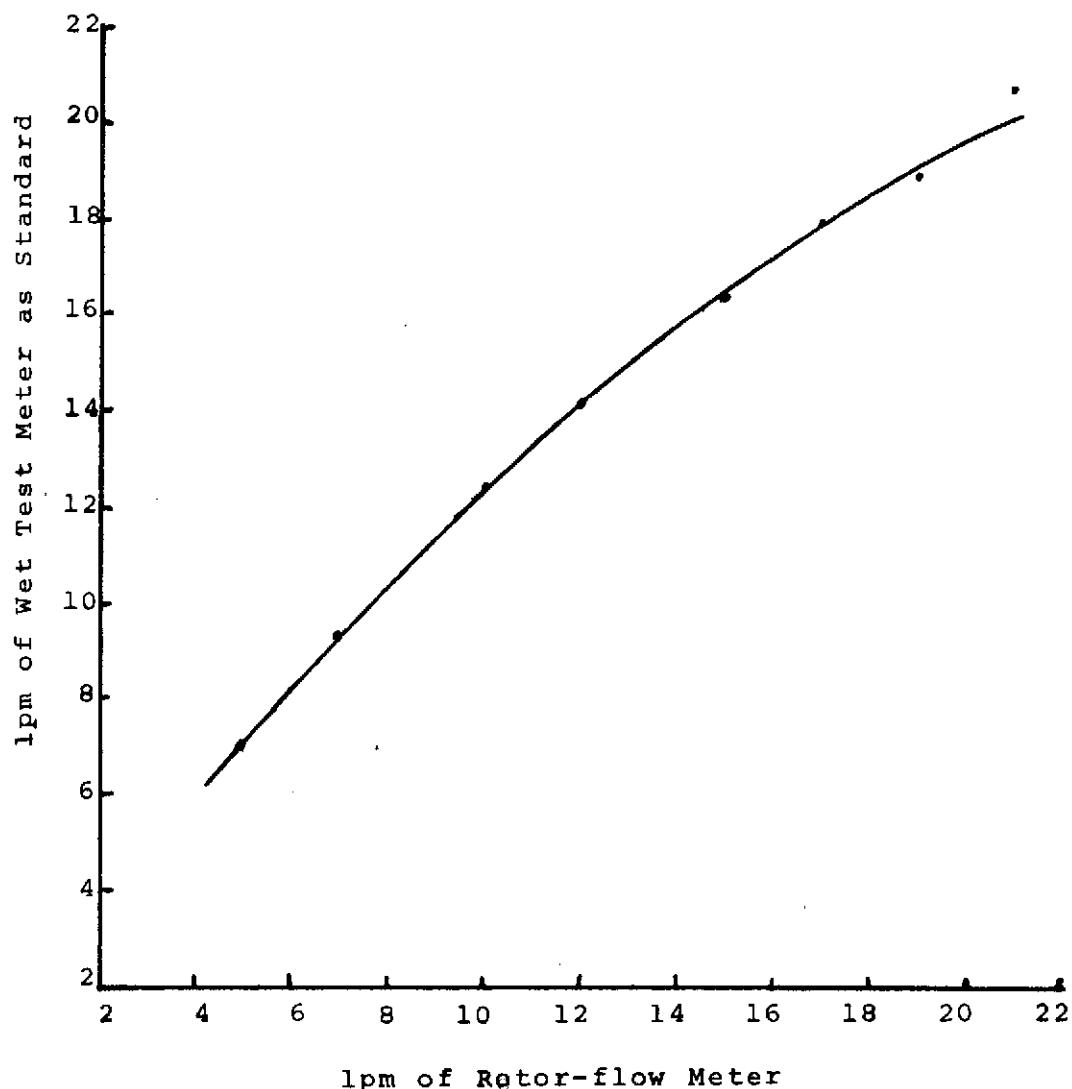


Figure 4. Calibration Curve for Rotor-flow Meter  
(steel ball as indicator, range: 5-35 lpm)

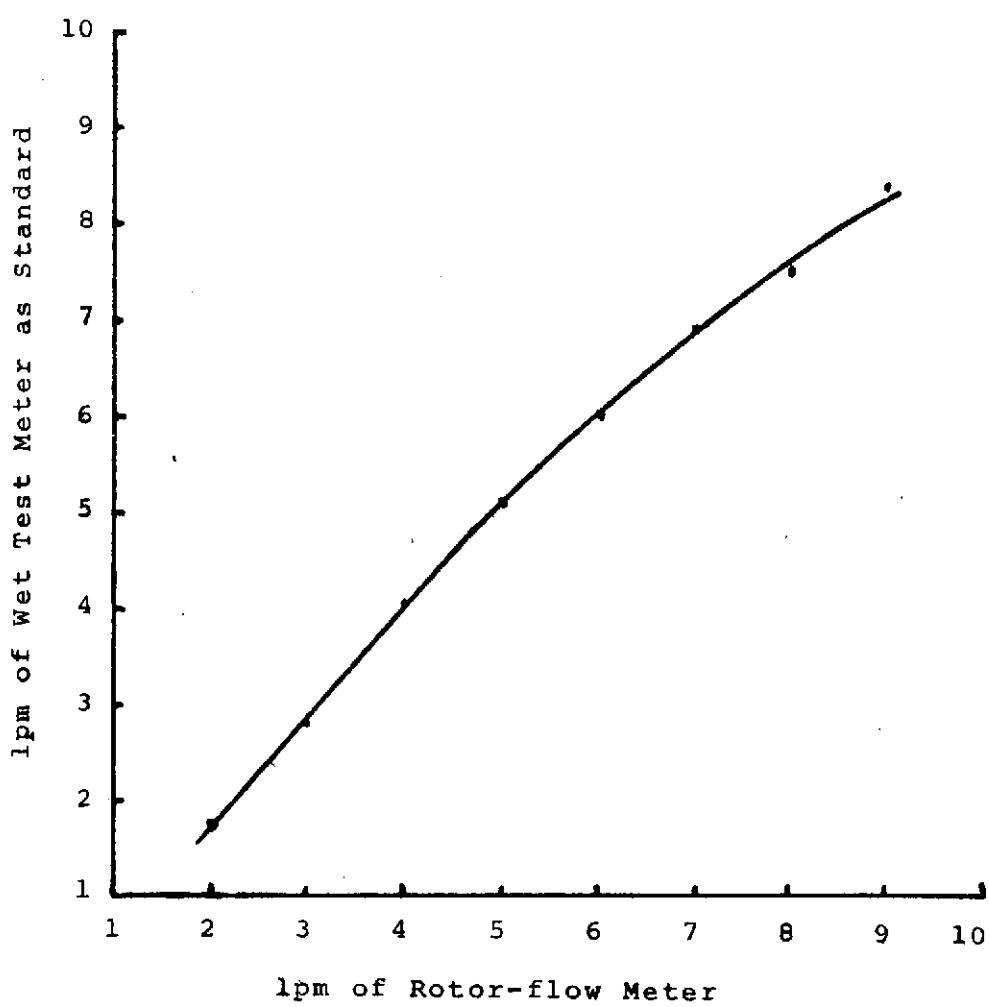


Figure 5. Calibration Curve for Rotor-flow Meter  
(glass red ball as indicator, range:  
1-10 lpm)

### C. High Volume Air Sampler

The high Volume Air Sampler consists of a blower unit which is attached to an adapter for holding a fiberglass filter, and a flowmeter to measure the amount of air drawn through the filter. During the sampling period air is sucked through the fiberglass filter at a measured rate. The filter is weighed before and after sampling. The difference in weight being the amount of suspended particulate matter per total volume of air passed through the filter. The weight of these particles is expressed in micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ). The particles ordinarily collected are within the size range of 0.1 to 100 micrometers in diameter.

The 8-hour average data for June 29, 1972 and July 2, 1972 were  $107 \mu\text{g}/\text{m}^3$  and  $93.6 \mu\text{g}/\text{m}^3$  respectively. Since city of Houston operates High Volume Air Samplers in its air sampling network, the suspended particulate mass data can be collected from them. A comparison, with analysis, of suspended particulate size and mass distribution in Houston can be made.

### D. Anderson Non-viable Particle Sampler

The Anderson Non-viable Particle Sampler is an 8-stage, 400-jet air sampler which automatically classifies air-borne particles according to their aerodynamic dimension. The sampler simulates the respiratory tract in collecting air-borne particulates. The eight stages are:

Stage 0,  $>11 \mu\text{m}$ ; stage 1,  $7-11 \mu\text{m}$ ; stage 2,  $4.7-7 \mu\text{m}$ ; stage 3,  $3.3-4.7 \mu\text{m}$ ; stage 4,  $2.1-3.3 \mu\text{m}$ ; stage 5,  $1.1-2.1 \mu\text{m}$ ; stage 6,  $0.65-1.1 \mu\text{m}$ ; stage 7,  $0.43-0.65 \mu\text{m}$ .

Air is drawn through the samples at the rate of one cubic foot per minute (1 cfm). Whatman filter paper is placed on each stage as a collecting plate. The filter was weighed before and after sampling. When assuming each particle is spherical in shape with the same density, the number of particles in each stage could be calculated. The satisfactory sampling time found is 24 hours. The tare weight was usually negative with 6 or 8-hour sampling periods. This was attributed to the lack of temperature and humidity control in the weighing room.

#### E. Millipore πMC Particle Measurement Computer System

Millipore πMC Particle Measurement Computer System is essentially an automated microscopic technique which consists of a microscope, a television camera, a television monitor and computer modules. Samples are placed on the microscope stage and the illumination and focus are adjusted while the operator is viewing the sample. A television camera picks up the sample image from the microscope and sends it to a digital computer for processing through counting and sizing logic. The image of sample is displayed on the television screen while the measurements and counts appear at the top of the television screen. The Millipore πMC system offers both speed and precision in counting particles, in determining size distributions, in characterizing shapes. The standard microscope is a Bausch & Lomb flat field Dynoptic instrument with 4x, 10x, 40x and 100x (oil immersion) objectives. With the 100x objective, particles as small as 0.5 micrometers can be resolved. But when known size of 0.481  $\mu\text{m}$  polystyrene latex sample is prepared and viewed, the πMC system can not resolve whether the sample size is 0.5  $\mu\text{m}$  or 0.7  $\mu\text{m}$ . Discussion with the manufacturers concluded that the instrument cannot be used to resolve images below 1  $\mu\text{m}$ .

#### F. Coulter Model 130 Portable Air Pollution Monitor

This is an instrument which uses the principle of forward light-scattering to measure the aerosol concentration and size distribution. It includes a digital printer containing five 6-digit channels. It can be programmed to sample automatically at 1 CFM (cubic foot per minute) for one minute cycles at 2, 10, or 60 minute intervals. The light source is a high intensity quartz iodine bulb. The five size ranges are: 0.5-1.0 $\mu\text{m}$ , 1.0-2.5  $\mu\text{m}$ , 2.5-5.0  $\mu\text{m}$ , and 10-50  $\mu\text{m}$ . This instrument was loaned to us by the manufacturer. But tremendous effort was spent in vain to adjust the flow rate to the prescribed 1 CFM and to zero the automatic counter by using clean helium gas. The manufacturer could not correct the problem and recommended contacting Royco Instrument Company.

#### G. Royco Model 220 Particle Counter

The Royco Model 220 Particle Counter is an aerosol light scattering instrument and is intended for use as a clean room monitor. The reading shows abnormal particle size distribution when used outside. Either filtering the air or reducing the flow rate from 1 CFM to 0.1 CFM did not correct this erratic behavior. Hence Model 220 Particle Counter can not be adapted for outdoor use. The suspended particulate size distributions obtained from Royco Model 220 Particle Counter are shown in Table 3.

#### H. Electrostatic Sampler

An aerosol with 0.02 to 10 micrometer size range is deposited on a collecting plate by using the Model 3100 Electrostatic Sampler manufactured by Thermo-System Inc. The sampler consists of a charging section and a collecting section. The charging power is 1600 volts and the precipitating power is 4200

Table 3. The Suspended Particulate Size Distribution Obtained from Royco-Model 220 Particle Counter.

Size Range ( $\mu$ m)	Counts/ $ft.^3$			
	Unfiltered Air		Filtered Air	
	A.M.	P.M.	A.M.	P.M.
0.5 - 0.7	30,000	50,000	25,000	5,000
0.7 - 1.4	300,000	300,000	55,000	8,000
1.4 - 3.0	4,000	10,000	550	150
3.0 - 5.0	50,000	60,000	5,000	1,800
5.0 -10.0	20,000	20,000	1,500	1,200

volts. The collecting plate is put in the collection section of the samples. Air is drawn through the charging section with a flow rate of 5 lpm. From calculation based on the number of particles in the atmosphere the collection time of 8 hours is shown to be required for optical microscope study. Figure 6 shows the number of cycles needed in order to obtain 5 particle per  $4.65 \times 10^{-6} \text{ cm}^2$  of microscope field for various aerosol concentration. Length of time vs number of intermittent cycles is shown in Figure 7.

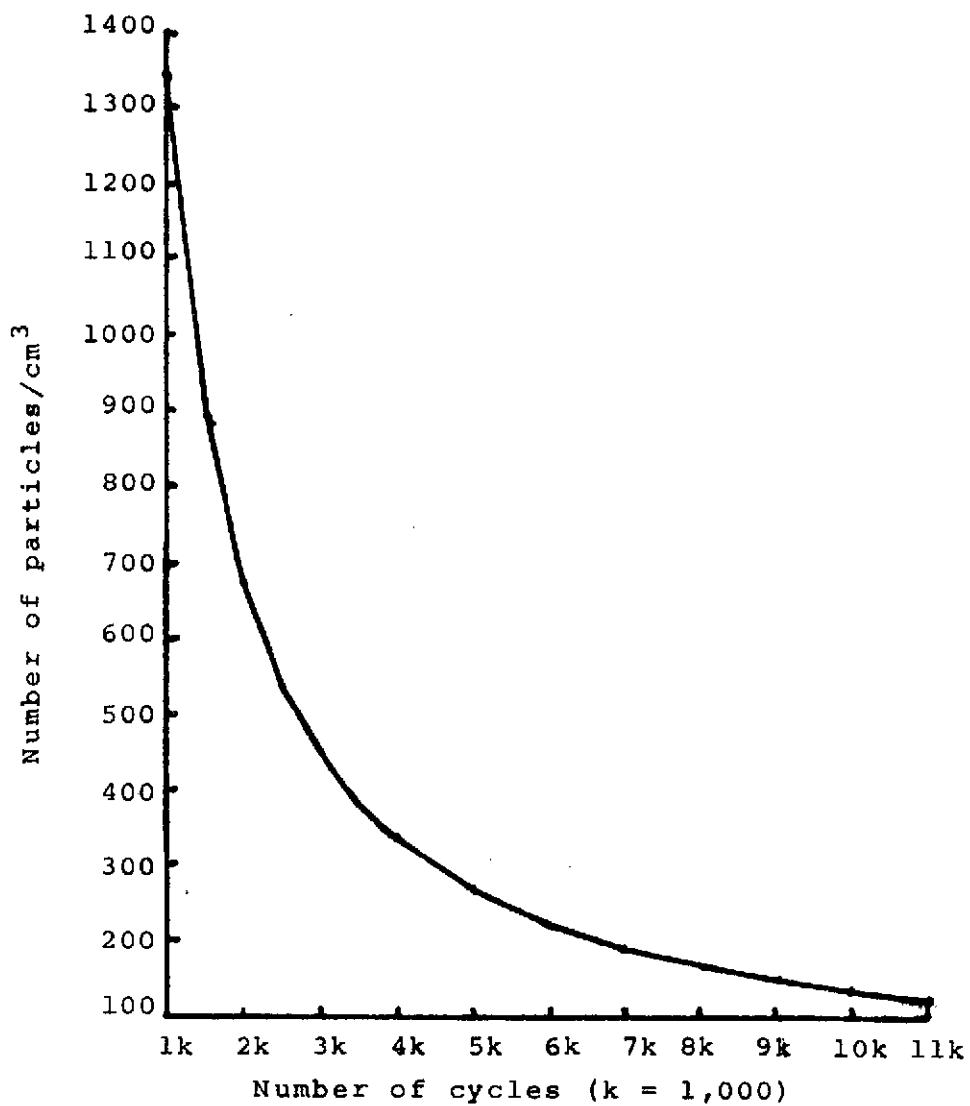
A glass slide, a collodion and carbon coated rod, and a silicon wafer are used as collection plates in order to be viewed in an optical microscope, and electron microscope and a scanning electron microscope respectively.

#### I. Wild-20 Optical Microscope

The glass slides used in collecting suspended particulate matter in the Electrostatic Sampler for 4, 6, and 8 hours were viewed in Wild-20 Optical Microscope. The particle sizing was done by utilizing the eyepiece micrometer. It was found that the 8 hour sample was suitable for particle sizing by optical microscopy. Optical microscopy can be used to measure the size of particles within the range of 0.5 to 2000  $\mu\text{m}$  with ease.

#### J. Electron Microscope

In the electron microscope a beam of electrons is focused on the specimen which usually consists of a thin foil (1,000 to 5,000  $\text{\AA}$  thick) the electron beam passes through the specimen,



**Figure 6.** Number of cycles needed in order to obtain 5 particles per  $4.65 \times 10^{-6} \text{ cm}^2$  of microscope field for Various Aerosol Concentration

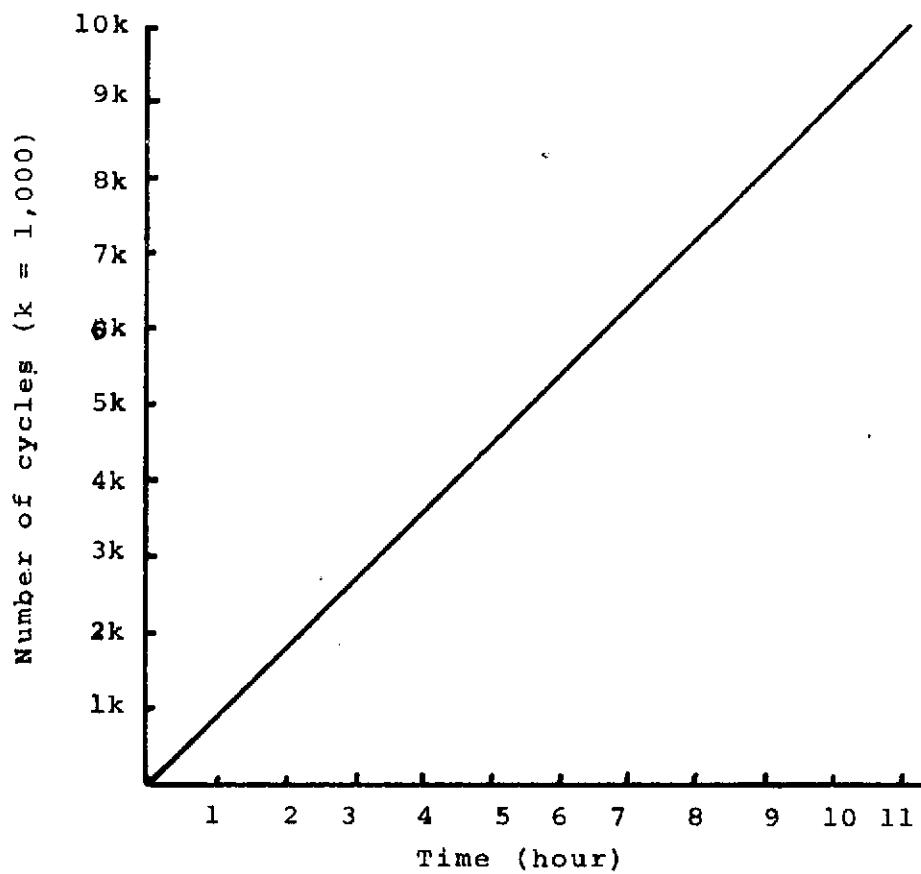


Figure 7. Length of time vs number of intermittent cycles (one cycles  $\cong$  4 sec.; 1 hour  $\cong$  900 cycles)

an objective lens, an intermediate lens and finally, a projector lens. This projector lens throws a greatly magnified view of the specimen area irradiated by the electron beam on a phosphor screen, below which is located a photographic plate for recording the image. Siemens Elmiskop I electron microscope is used and operated at a voltage of 80 KV.

The electron microscope grids are prepared in the following manner. First eight to ten 200 mesh electron microscope grids are laid on a glass microscope slide. They are coated with a thin film of collodion (nitro cellulose solutions). In order to stabilize the collodion net, carbon is evaporated onto it by using Vacuum Evaporator VE 10 of Mikros, Inc. (Portland, Oregon). Then the electron microscope grids are used to collect suspended particulate matter in the Electrostatic Sampler for 2, 4, and 6 hours and are then photographed in the Siemens Elmiskop I electron microscope with magnifications 3,000x, 6,000x, and 10,000x. The electron micrographs are shown in Figures 8-12. It can be seen that the 6 hours sample has ample particulates for particle sizing. The Siemens Elmiskop I electron microscope operates efficiently in the 0.05 to 10  $\mu\text{m}$  particle size range..

#### K. ETEC "Autoscan" Scanning Electron Microscope

ETEC "Autoscan" Scanning Electron Microscope (SEM) is a kind of electron-optical instrument which by focussing a Scanning electron beam on a specimen surface and recording the emitted secondary electrons as a function of position. SEM consists of three main components. The electron-optical column (a triod electron gun and a four lens system) together with the associated electronics; the vacuum system including the specimen



[  
1.2  $\mu\text{m}$

**Figure 8.** Electron micrograph of 2 hours suspended particle sample; magnification = 3,000x.



Figure 9. Electron micrograph of 4 hours suspened particle sample; magnification = 3,000 x.

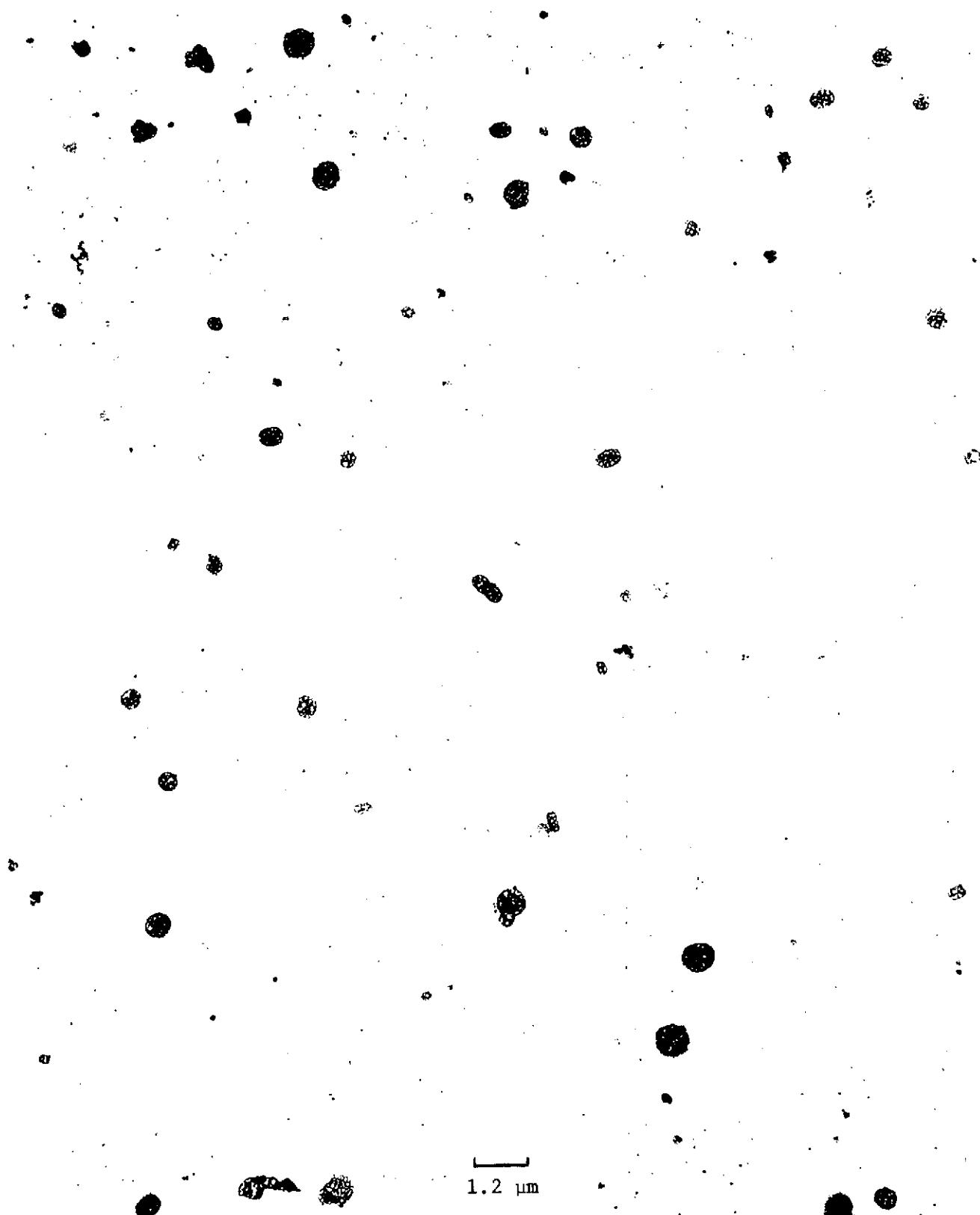


Figure 10. Electron micrograph of 6 hours suspended particle sample; magnification = 3,000x.

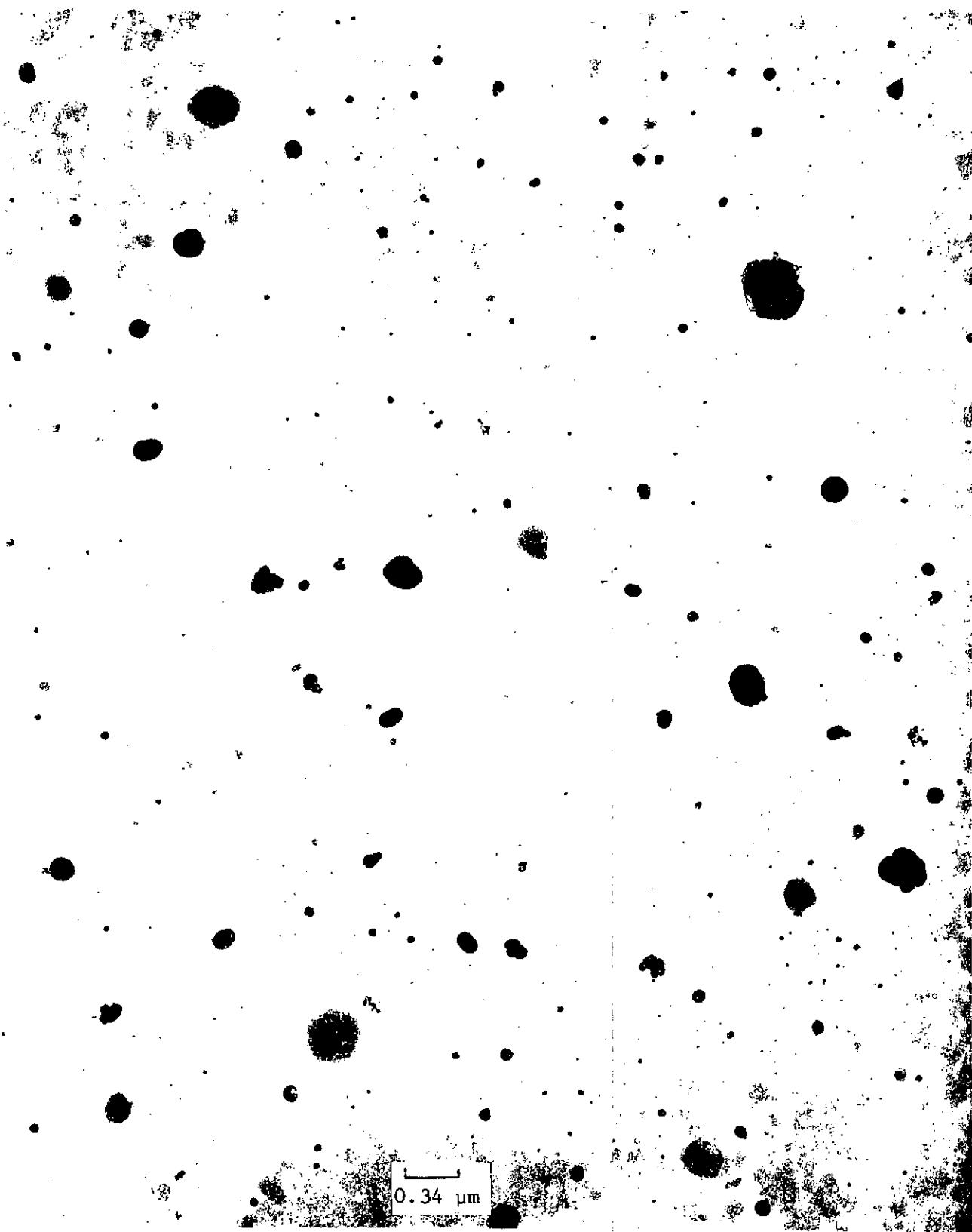


Figure 11. Electron micrograph of 6 hours suspended particle sample (same field as in Fig. 10); Magnification = 10,000X.

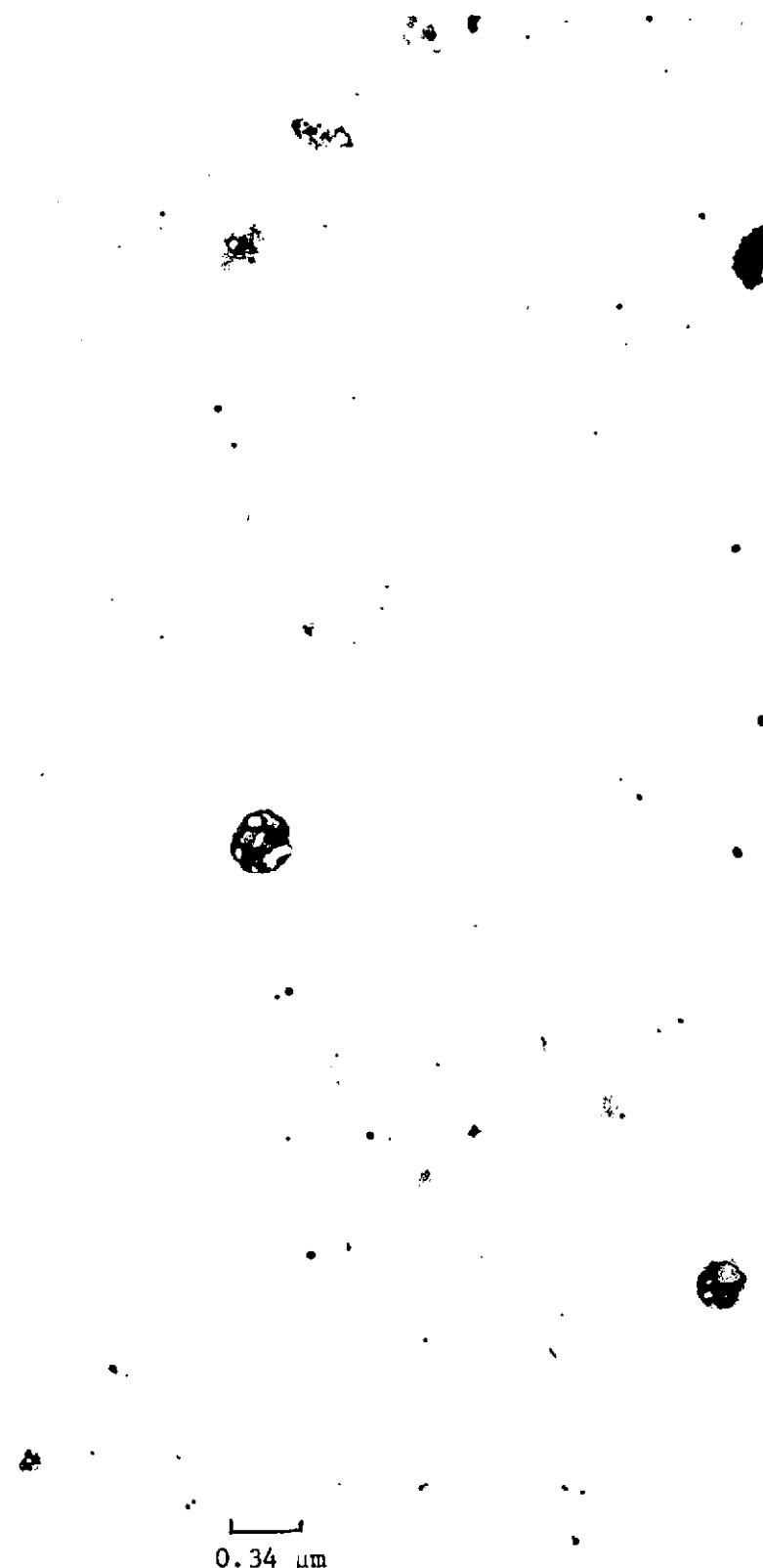


Figure 12. Electron micrograph of 6 hours suspended particle sample (different field from Fig. 11); magnification = 10,000 x.

chamber and stage; and finally the signal detection and display system. The electron beam can be accelerated at 2.5, 5, 10, 20, and 30 KV. There kinds of magnifications exist: low magnification (<5,000x, 1mm scale on photograph = 0.1  $\mu$ m); medium magnification (5,000 - 20,000x, 1mm scale = 0.1 - 0.025  $\mu$ m), and high magnification (20,000 - 50,000x, 1mm scale = 0.025-0.01  $\mu$ m). The effective particle size range in SEM is 0.01 to 500 $\mu$ m.

The silicon wafer was used to collect suspended particulate matter in Electrostatic Samples for 6 hours. At low magnifications of the SEM, the viewed field contained sufficient number of particles but sizing was difficult. While at the medium magnification of the SEM, the sizing was easy but too few particles were present in the microscope field for the count to be statistically significant. This problem can be solved by increasing the air sampling time. But the availability of personnel for operating SEM for particle sizing is also a problem.

#### L. Royco Model 225 Particle Monitor

It was found in the above studies that the Andersen Sampler, the optical microscope, the electron microscope, and the scanning electron microscope could be used for the suspended particulate size distribution measurement. In addition to being tedious and time consuming, the sampling time is from 6 to 24 hours which is not easily suited to real-time measurement. Therefore the light scattering device became greatly interesting since it had a

continuous monitoring capability. The Royco Model 225 Particle Counter was chosen and then used for the suspended particulate size distribution measurements in Houston.

The Royco Model 225 Aerosol Particle Monitor is an instrument used for measuring the amount and size of particles in the gaseous phase, and for recording the data on a chart recorder. It utilizes the principle of forward light scattering to detect particles in the gaseous phase and to generate signal pulses proportional to the quantity and size of the particles. The monitor consists of a monitor main-frame, plug-in module, and a sensor which are cable connected as shown in Figure 13. The sensor contains the aerosol sampling cell, the light source, the optics, and a photo multiplier tube, all of which together are necessary to detect the particles and generate the corresponding data signal pulses. The layout of optics components of the sensor is shown in Figure 14. The monitor main-frame contains the vacuum pump that moves the aerosol sample through the sensor and the electronics for processing the data-signals. The plug-in module contains additional signal processing electronics and digital display. The digital display shows the total number of particles from any one of five separate channels which correspond to five particle size ranges. The permanent, printed data is processed by the Model DPAGE Digital Drum Printer (MFE Corporation) which has the maximum print rate of 400 MSECS/line (or 2 and 1/2 lines/sec.)

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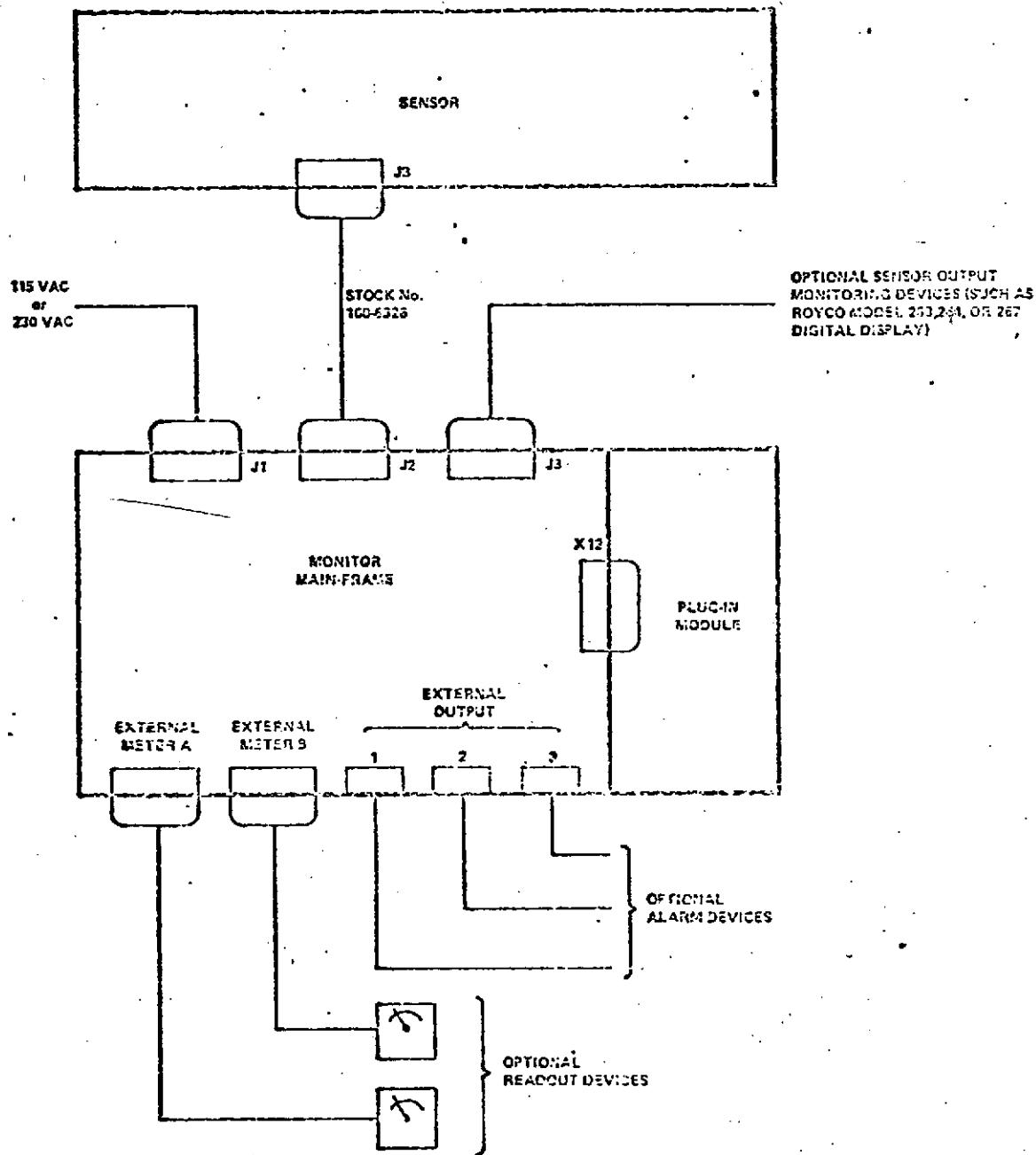


Figure 13. Typical Cabling Diagram of Royco Model 225 Aerosol Particle Monitor.

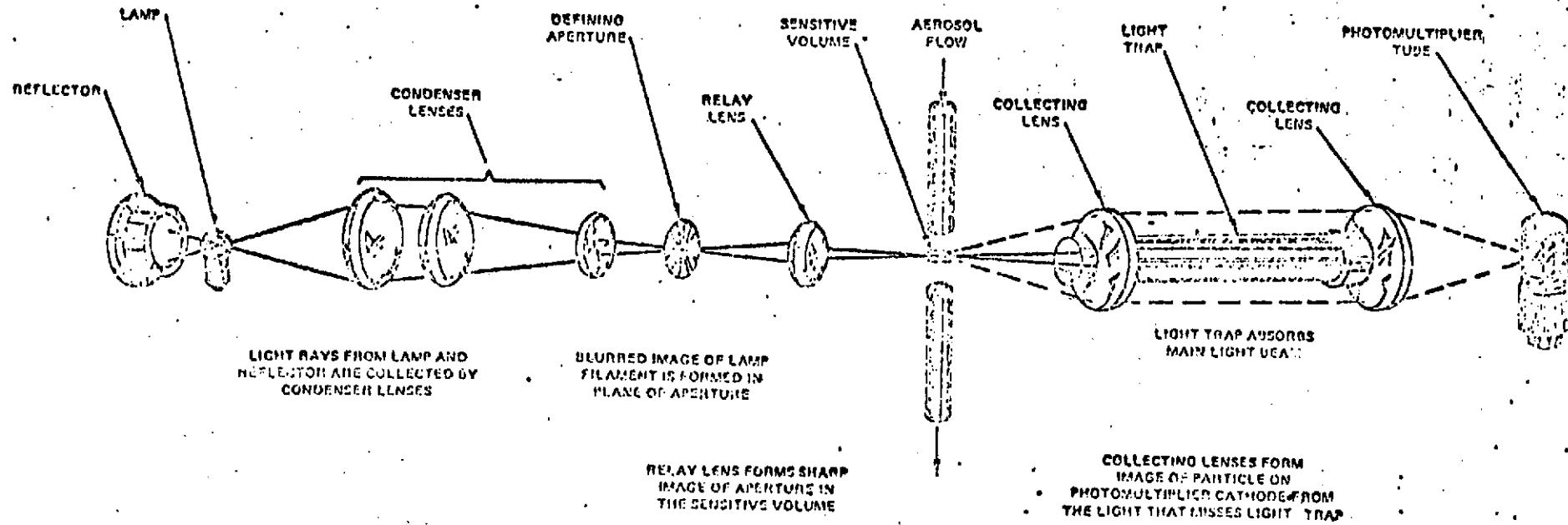


Figure 14. Layout of Optics Components of Royco Model 225 Aerosol Particle Monitor.

The monitor will detect concentrations of up to  $10^8$  particles per cubic feet of 0.3 micronmeter ( $\mu\text{m}$ ) diameter and larger. The five particles size ranges are 0.3 - 0.5  $\mu\text{m}$ , 0.5 - 0.7  $\mu\text{m}$ , 0.7 - 1.4  $\mu\text{m}$ , 1.4 - 3.0  $\mu\text{m}$ , and 3.0 - 10.0  $\mu\text{m}$ .

### 1. Instrumental Considerations

The Instrument was tested inside and outside at the School of Public Health, The University of Texas at Houston (UT-SPH). The results are shown in Table 4. For the indoor particle concentration, the sample size was too small to be counted for 1.4 - 3.0  $\mu\text{m}$  and 3.0 - 10.0  $\mu\text{m}$  size particles on  $0.01 \text{ ft}^3/\text{m}$  (cubic feet per minute) and X10 count scale setting. While the counting ability was not fully utilized on :  $0.1 \text{ ft}^3/\text{m}$  and X10 count scale setting, and on  $0.01 \text{ ft}^3/\text{m}$  and X1 count scale setting. Only on  $0.1 \text{ ft}^3/\text{m}$  and X1 count scale setting, the counting ability was optimumully utilized. As to the outdoor particle concentration, the sample size overloads the counting ability on  $0.1 \text{ ft}^3/\text{m}$  and X1 count scale setting. On settings:  $0.1 \text{ ft}^3/\text{m}$  and X10 count scale, and  $0.01 \text{ ft}^3/\text{m}$  and X10 count scale, and counting ability was not fully utilized but was on  $0.01 \text{ ft}^3/\text{m}$  and X1 count scale. Thus for best utilization of this instrument, the particle concentration in the air to be monitored has to be found first and then set at the proper flow rate and count scale.

### 2. Preliminary Results

The comparison of indoor and outdoor suspended particle size distribution is shown in Table 5. As to percentage distribution, 0.3 - 0.5  $\mu\text{m}$ , and 0.5 - 0.7  $\mu\text{m}$  size

Table 4. The Testing of the Royco Model 225 Aerosol Particle Monitor

Location	Temp. (°F)	Humidity (%)	Flow rate ft <sup>3</sup> /m <sup>3</sup>	Count Scale	Particle Counts/ft <sup>3</sup>				
					0.3-0.5 μm	0.5-0.7 μm	0.7-1.4 μm	1.4-3.0 μm	3.0-10.0 μm
Indoor	65/76	55	0.1	x 10	517,450	161,700	31,600	6,500	350
			0.1	x 1	653,085	210,405	42,220	8,060	305
			0.01	x 1	639,050	129,750	11,750	2,000	252
			0.01	x 10	518,000	112,500	3,500	---	---
Outdoor	78/91	78	0.1	x 1	4,041,230	1,829,970	1,242,445	419,370	6,595
			0.1	x 10	4,331,900	2,158,400	848,050	276,600	9,250
			0.01	x 1	7,822,350	2,953,100	893,500	169,800	11,550
			0.01	x 10	6,443,000	2,058,000	552,500	107,000	10,000

Table 5. The Comparison of Indoor and Outdoor Suspended Particle Size Distribution  
number of particles per ft<sup>3</sup>

Location		0.3-0.5 $\mu\text{m}$	0.5-0.7 $\mu\text{m}$	0.3-0.7 $\mu\text{m}$	0.7-1.4 $\mu\text{m}$	1.4-3.0 $\mu\text{m}$	3.0-10.0 $\mu\text{m}$	0.3-10.0 $\mu\text{m}$
Indoor	Particle Counts/ft <sup>3</sup> ( $N_I$ )	653,085	210,405	863,490	42,220	8,060	305	914,075
	Percentage ( $P_I$ )	.71.45	23.02	94.47	4.62	0.88	0.03	100.00
Outdoor	Particle Counts/ft <sup>3</sup> ( $N_O$ )	7,822,350	2,953,100	10,775,450	893,500	169,800	11,550	11,850,300
	Percentage ( $P_O$ )	66.01	24.92	90.93	7.54	1.43	0.10	100.00
	$P_O/P_I$	0.92	1.08	0.96	1.63	1.63	3.33	1.00
	$N_O/N_I$	11.98	14.04	12.48	21.16	21.07	37.87	12.96

particle ranges in outdoor air were 1.6 times more than the indoor air, and increased to 3.3 times more for 3.0 - 10.0  $\mu\text{m}$  size particles. In speaking of absolute number of particles the outdoor air had more particles than indoor air and the number increased with increasing particle size: outdoor air had 12.0 times more particles than indoor air in 0.3 - 0.5  $\mu\text{m}$  size range, 1.4 - 3.0  $\mu\text{m}$ , and 37.9 times in 3.0 - 10.0  $\mu\text{m}$ .

#### IV. SUSPENDED PARTICULATE SIZE DISTRIBUTION IN HOUSTON

##### A. Suspended Particulate Size Distribution Measurement in Houston

The Houston city air pollutant sampling network consists of 17 stations which are shown in Table 1 and Figure 1. Among them only stations 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 16, and P1 were chosen for sampling in this project. The Royco Model 225 Aerosol Particle Monitor was transported to each station by VW station wagon via the established route as shown in Appendix 1. The time taken for each trip was about 7-8 hours.

The data was taken on four time periods: August 23, 25, and 28, 1972; October 4, 5, and 6, 1972; November 29, December 1, and 4, 1972; and February 5, 6, and 15, 1973. The raw data was shown in Appendixes 2, 3, 4, and 5. The treated data was shown in Tables 6-19. The particle mass concentration data was taken by the Department of Public Health, City of Houston on August 19, 25, and 31, 1972; November 29, December 5, and 9, 1972; and February 9, and 15, 1973, and was shown in Tables 20-22.

##### B. Isopleth Maps of Suspended Particle Size and Mass Distribution in Houston

The isopleth maps were prepared by using the SYMAP computer program on the basis of trend-surface analysis. Basically, each point in the area concerned is treated as a centroid in a grid pattern and the contour of a surface is estimated on the basis of several points rather than the first closest point. In execution, a data package is used first to draw the political map with

Table 6. Suspended Particulate Size Distribution in Houston on August 25, 1972

number of particles per m<sup>3</sup>

Station	0.3-0.5 $\mu\text{m}$	0.5-0.7 $\mu\text{m}$	0.3-0.7 $\mu\text{m}$	0.7-1.4 $\mu\text{m}$	1.4-3.0 $\mu\text{m}$	3.0-10.0 $\mu\text{m}$	0.3-10.0 $\mu\text{m}$ (Total)
Pl	2,585,398	1,866,310	4,451,708	1,432,527	1,200,010	82,272	7,166,518
2	3,082,740	1,820,231	4,902,970	1,450,535	1,300,997	133,472	7,787,974
3	3,908,111	2,704,393	6,612,504	1,734,427	1,491,141	162,250	10,000,322
4	2,269,903	1,585,949	3,855,852	1,489,199	1,981,774	152,010	7,478,835
5	1,805,047	1,383,093	3,188,140	1,290,757	1,562,821	124,997	6,166,715
7	6,016,824	2,090,105	8,106,929	1,901,267	2,153,557	185,625	12,347,377
8	1,418,403	926,534	2,344,937	1,405,162	1,627,085	146,713	5,523,896
9	1,383,093	1,266,746	2,649,839	1,356,081	1,888,732	167,016	6,061,668
10	1,266,217	1,382,916	2,649,133	1,360,671	1,577,651	160,837	5,748,292
11	1,186,063	1,393,686	2,579,749	1,309,295	1,416,814	147,949	5,453,806
12	1,704,237	1,462,717	3,166,954	1,194,361	1,873,196	161,190	6,395,700
13	5,524,956	4,709,295	10,234,250	3,255,229	3,355,156	148,126	16,992,761
14	5,270,900	2,762,125	8,033,025	2,077,464	2,228,061	240,814	12,579,364
16	30,798,618	18,135,040	48,933,657	9,161,709	7,298,224	230,574	65,624,165

Table 7. Three-Day Average of Suspended Particulate Size Distribution in Houston on August 23, 25, and 28, 1972

number of particles per m<sup>3</sup>

Station	0.3-0.5 µm	0.5-0.7 µm	0.3-0.7 µm	0.7-1.4 µm	1.4-3.0 µm	3.0-10.0 µm	0.3-10.0 µm (Total)
P1	6,308,073	3,640,520	9,948,593	1,932,575	1,131,567	123,349	13,136,085
2	48,104,049	18,500,498	66,604,547	3,612,566	2,357,825	292,838	72,867,776
3	10,096,895	4,909,738	15,006,632	2,584,633	1,552,463	198,266	19,342,006
4	3,308,547	1,638,649	4,947,196	1,135,217	1,268,070	117,494	7,467,977
5	4,223,340	1,780,065	6,003,406	1,113,236	1,183,944	15,464	8,416,050
6	9,023,471	4,413,750	13,437,221	1,634,500	658,532	114,758	15,845,009
7	6,530,832	3,583,170	10,623,426	1,874,814	1,398,923	170,723	14,075,861
8	3,643,727	1,859,601	5,503,328	775,937	603,095	112,109	6,994,470
9	2,104,211	1,066,362	3,170,573	457,529	344,360	88,275	4,060,738
10	3,421,598	2,180,981	5,602,579	1,043,469	937,539	136,002	7,719,590
11	2,268,314	1,452,242	3,720,556	863,506	874,570	134,649	5,593,281
12	3,137,706	1,884,083	5,021,788	958,608	1,123,505	150,244	7,254,145
13	4,275,629	2,793,786	7,069,415	1,541,223	1,509,304	134,708	10,335,649
14	11,577,678	6,668,117	18,245,795	3,194,731	2,894,996	747,042	25,082,576
15	11,369,644	7,415,100	18,784,743	2,369,831	1,629,733	176,550	22,960,857
16	15,089,257	8,652,127	23,739,384	4,071,537	3,239,281	165,133	31,215,335

Table 8. Three-Day Average of Suspended Particulate Size Distributions in Houston on August 23, 25, and 28, 1972.

number of particles per ft<sup>3</sup>

Station	0.3-0.5 $\mu\text{m}$	0.5-0.7 $\mu\text{m}$	0.3-0.7 $\mu\text{m}$	0.7-1.4 $\mu\text{m}$	1.4-3.0 $\mu\text{m}$	3.0-10.0 $\mu\text{m}$	0.3-10.0 $\mu\text{m}$ (Total)
P1	178,648	103,102	281,750	54,732	32,047	3,493	372,022
2	1,362,335	523,945	1,886,280	102,310	66,775	8,293	2,063,658
3	285,950	139,047	424,997	73,198	43,967	5,615	547,777
4	93,700	46,407	140,107	32,150	35,913	3,328	211,498
5	119,608	50,413	170,020	31,528	33,530	3,270	238,348
6	255,550	125,000	380,550	46,290	18,650	3,250	448,740
7	199,384	101,478	300,862	53,096	39,618	5,061	398,637
8	103,193	52,665	155,858	21,975	17,080	3,175	198,088
9	59,593	30,200	89,793	12,958	9,753	2,500	115,003
10	96,902	61,767	158,668	29,552	26,552	3,852	218,623
11	64,240	41,128	105,368	24,455	24,768	3,813	158,405
12	88,862	53,358	142,220	27,148	31,813	4,255	205,442
13	121,088	79,122	200,210	43,648	45,038	3,815	292,712
14	327,887	188,845	516,732	90,477	81,988	21,157	710,353
15	321,995	210,000	531,995	67,115	46,155	5,000	650,265
16	427,280	245,033	672,313	115,308	91,738	4,677	884,037

Table 9. Three-Day Average of Suspended Particulate Size Distribution in Houston on August 23, 25, and 28, 1972

Percentage

Station	0.3-0.5 $\mu\text{m}$	0.5-0.7 $\mu\text{m}$	0.3-0.7 $\mu\text{m}$	0.7-1.4 $\mu\text{m}$	1.4-3.0 $\mu\text{m}$	3.0-10.0 $\mu\text{m}$
P1	48.02	27.71	75.73	14.71	8.61	0.94
2	66.02	25.39	91.40	4.96	3.24	0.40
3	52.20	25.38	77.59	13.36	8.03	1.03
4	44.30	21.94	66.25	15.20	16.98	1.58
5	50.18	21.15	71.33	13.23	14.07	1.37
6	56.95	27.86	84.80	10.32	4.16	0.72
7	50.02	25.46	75.47	13.32	9.94	1.27
8	52.09	26.59	78.68	11.09	8.62	1.60
9	51.82	26.26	78.08	11.27	8.48	2.17
10	44.32	28.25	72.58	13.52	12.14	1.76
11	40.55	25.96	66.52	15.44	15.64	2.41
12	43.25	25.97	69.23	13.21	15.49	2.07
13	41.37	27.03	68.40	14.91	15.39	1.30
14	46.16	26.58	72.74	12.74	11.54	2.98
15	49.52	32.29	81.81	10.32	7.10	0.77
16	48.33	27.72	76.05	13.04	10.38	0.53

Table 10. Suspended Particulate Size Distribution in Houston on November 29, 1972

number of particles per m<sup>3</sup>

Station	0.3-0.5 $\mu\text{m}$	0.5-0.7 $\mu\text{m}$	0.3-0.7 $\mu\text{m}$	0.7-1.4 $\mu\text{m}$	1.4-3.0 $\mu\text{m}$	3.0-10.0 $\mu\text{m}$	total 0.3-10.0 $\mu\text{m}$
P1	5,587,631	2,054,336	7,641,967	947,897	382,407	42,372	9,014,643
2	8,810,021	4,331,301	13,141,323	1,349,195	502,285	62,675	15,055,478
3	8,414,726	3,514,757	11,929,484	1,355,198	548,541	79,624	13,912,846
4	13,033,274	3,636,754	16,670,028	1,192,772	270,475	28,248	18,161,522
5	4,712,296	1,752,082	6,464,378	587,735	326,971	49,258	7,428,341
7	5,513,657	2,829,214	8,342,870	1,192,066	581,203	49,081	10,165,219
8	5,881,763	2,431,623	8,313,386	1,437,823	594,797	38,488	10,384,495
9	5,368,356	2,290,736	7,659,092	1,379,562	485,336	33,721	9,557,711
10	5,094,174	2,297,798	7,391,972	1,130,803	320,968	36,016	8,879,759
11	2,816,502	983,913	3,800,415	448,084	235,871	22,598	4,506,968
12	2,776,425	1,015,869	3,792,294	414,363	140,887	12,712	4,360,255
13	2,311,166	983,384	3,314,550	402,358	108,931	12,182	3,838,021
14	3,412,535	1,704,590	5,117,125	463,444	127,646	15,536	5,723,751
16	2,183,570	921,768	3,105,338	324,322	106,989	12,712	3,549,361

Table 11

Three-Day Average of Suspended Particulate Size Distribution in Houston on November 29, December 1, and 4, 1972.

number of particles per m<sup>3</sup>

Station	0.3-0.5 μm	0.5-0.7 μm	0.3-0.7 μm	0.7-1.4 μm	1.4-3.0 μm	3.0-10.0 μm	total 0.3-10.0 μm
P1	9,914,754	3,813,127	13,727,881	1,746,197	687,545	46,492	16,208,114
2	11,218,988	5,405,255	16,624,242	2,251,013	1,211,780	93,042	20,180,077
3	11,307,969	4,922,391	16,230,359	2,339,405	702,963	55,966	19,328,694
4	15,098,733	6,891,394	21,990,126	4,085,132	1,319,358	57,379	27,451,995
5	11,129,947	4,615,488	15,745,435	2,281,615	652,211	49,022	18,728,283
7	9,988,081	4,382,560	14,370,640	2,527,137	976,969	42,490	17,917,236
8	9,162,945	3,997,681	13,160,626	2,680,147	1,341,133	35,899	17,217,803
9	8,777,713	4,092,135	12,869,848	2,216,056	694,489	30,661	15,811,053
10	9,620,975	4,754,433	14,375,407	2,304,978	658,473	33,545	17,372,402
11	8,395,011	3,713,553	12,108,564	1,774,210	605,979	28,307	14,517,059
12	6,262,111	2,838,630	9,100,741	1,085,135	262,471	30,249	10,478,596
13	6,547,063	3,184,256	9,731,318	1,330,363	368,754	20,598	11,451,033
14	9,693,537	4,867,189	14,560,726	1,794,925	460,913	28,130	16,844,694
16	9,236,861	4,347,191	13,584,051	1,807,813	555,368	28,660	15,975,892

Table 12

Three-Day Average of Suspended Particulate Size Distribution in Houston on November 29, December 1, and 4, 1972.

number of particles per ft<sup>3</sup>

Station	0.3-0.5 $\mu\text{m}$	0.5-0.7 $\mu\text{m}$	0.3-0.7 $\mu\text{m}$	0.7-1.4 $\mu\text{m}$	1.4-3.0 $\mu\text{m}$	3.0-10.0 $\mu\text{m}$	Total 0.3-10.0 $\mu\text{m}$
P1	280,792	107,990	388,782	49,453	19,472	1,317	459,023
2	317,728	153,080	470,808	63,750	34,318	2,635	571,512
3	320,248	139,405	459,653	66,253	19,908	1,585	547,400
4	427,605	195,168	622,773	115,693	37,365	1,625	777,457
5	315,207	130,713	445,920	64,617	18,471	1,388	530,396
7	282,868	124,117	406,985	71,570	27,668	1,203	507,427
8	259,500	113,217	372,717	75,903	37,982	1,017	487,618
9	248,590	115,892	364,482	62,760	19,668	868	447,778
10	272,472	134,648	407,120	65,278	18,648	950	491,997
11	237,752	105,170	342,922	50,247	17,162	802	411,132
12	177,347	80,392	257,738	30,732	7,433	857	296,760
13	185,417	90,180	275,597	37,677	10,443	583	324,300
14	274,527	137,842	412,368	50,833	13,053	797	477,052
16	261,593	123,115	384,708	51,198	15,728	812	452,447

Table 13

Three Day Average of Suspended Particulate Size Distribution in Houston on November 29, December 1, and 4, 1972

## Percentage

Station	0.3-0.5 $\mu\text{m}$	0.5-0.7 $\mu\text{m}$	0.3-0.7 $\mu\text{m}$	0.7-1.4 $\mu\text{m}$	1.4-3.0 $\mu\text{m}$	total 3.0-10.0 $\mu\text{m}$
P1	61.17	23.53	84.70	10.77	4.24	0.29
2	55.59	26.79	82.38	11.15	6.00	0.46
3	58.50	25.47	83.97	12.10	3.64	0.29
4	55.00	25.10	80.10	14.88	4.81	0.21
5	59.43	24.64	84.07	12.18	3.48	0.26
7	55.75	24.46	80.21	14.10	5.45	0.24
8	53.22	23.22	76.44	15.57	7.79	0.21
9	55.52	25.88	81.40	14.02	4.39	0.19
10	55.38	27.37	82.75	13.27	3.79	0.19
11	57.83	25.58	83.41	12.22	4.17	0.19
12	59.76	27.09	86.85	10.36	2.50	0.29
13	57.17	27.81	84.98	11.62	3.22	0.18
14	57.55	28.89	86.44	10.66	2.74	0.17
16	57.82	27.21	85.03	11.32	3.48	0.18

Table 14  
Suspended Particulate Size Distribution in Houston on February 15, 1973.

Number of Particles per m<sup>3</sup>

Station	0.3-0.5μm	0.5-0.7μm	0.3-0.7μm	0.7-1.4μm	1.4-3.0μm	3.0-10.0μm	0.3-10.0μm
P1	4,733,129	3,656,527	8,389,656	1,180,766	672,479	51,200	10,294,101
2	5,148,198	1,667,338	6,815,536	516,232	228,279	33,545	7,593,592
3	2,851,636	885,398	3,737,034	214,861	189,615	34,251	4,175,761
4	2,764,597	1,092,138	3,856,735	257,233	101,869	11,652	4,227,490
5	3,163,070	1,586,302	4,749,372	225,984	96,220	11,652	5,083,228
7	3,134,292	1,217,842	4,352,134	290,072	117,406	12,005	4,771,617
8	2,981,223	999,803	3,981,026	173,372	92,159	8,651	4,255,208
9	2,476,820	930,242	3,407,062	230,045	64,441	6,886	3,708,433
10	4,240,908	1,306,117	5,547,025	162,956	122,879	14,654	5,847,513
11	2,806,969	838,259	3,645,228	166,134	55,790	7,768	3,874,919
12	2,713,220	823,782	3,537,003	241,344	115,640	10,946	3,904,933
13	2,678,970	728,622	3,407,592	300,488	128,352	17,479	3,853,910
14	4,064,005	1,495,555	5,559,560	285,835	98,692	10,770	5,954,855
16	3,176,664	810,011	3,986,676	278,243	99,927	12,535	4,377,381

Table 15

Three-Day Average of Suspended Particulate Size Distribution in Houston on February 5, 6, and 15, 1973

Number of Particles per m<sup>3</sup>

Station	0.3-0.5µm	0.5-0.7µm	0.3-0.7µm	0.7-1.4µm	1.4-3.0µm	3.0-10.0µm	0.3-10.0µm
P1	3,414,712	2,508,776	5,923,488	1,050,061	593,973	77,094	7,644,615
2	3,744,448	1,962,412	5,706,861	802,596	479,863	85,156	7,074,476
3	2,519,839	1,534,573	4,054,412	743,217	510,347	78,035	5,386,011
4	3,999,093	2,842,926	6,842,019	1,970,004	1,176,882	72,562	10,061,467
5	3,609,447	2,113,480	5,722,927	1,218,725	896,521	93,277	7,931,450
7	3,535,414	1,711,005	5,246,419	886,752	572,905	86,510	6,792,585
8	6,716,256	5,018,728	11,734,984	2,724,579	1,308,706	88,393	15,856,662
9	1,966,767	1,063,361	3,030,128	634,285	435,431	79,918	4,179,762
10	5,383,068	4,033,697	9,416,765	2,737,467	1,621,200	73,916	13,849,347
11	2,554,443	1,283,636	3,838,079	670,419	444,847	72,268	5,025,613
12	2,970,336	1,577,357	4,547,693	685,603	415,716	69,737	5,718,749
13	4,201,125	1,980,656	6,181,781	911,881	506,463	70,561	7,670,686
14	4,596,832	2,954,152	7,550,985	1,686,759	885,045	90,923	10,213,712
16	16,596,877	10,331,294	26,928,171	5,602,461	3,870,859	72,680	36,474,171

Table 16

Three-Day Average of Suspended Particulate Size Distribution in Houston on February 5,6, and 15, 1973

number of particles per ft<sup>3</sup>

Station	0.3-0.5 $\mu\text{m}$	0.5-0.7 $\mu\text{m}$	0.3-0.7 $\mu\text{m}$	0.7-1.4 $\mu\text{m}$	1.4-3.0 $\mu\text{m}$	3.0-10.0 $\mu\text{m}$	total 0.3-10.0 $\mu\text{m}$
P1	96,707	71,050	167,757	29,738	16,822	2,183	216,500
2	106,045	55,577	161,622	22,730	13,590	2,412	200,353
3	71,363	43,460	114,823	21,048	14,453	2,210	152,535
4	113,257	80,513	193,770	55,792	33,330	2,055	284,947
5	102,222	59,855	162,077	34,515	25,390	2,642	224,623
7	100,125	48,457	148,582	25,113	16,225	2,450	192,370
8	190,208	142,133	332,342	77,162	37,063	2,503	449,070
9	55,700	30,115	85,815	17,963	12,332	2,263	118,373
10	152,452	114,237	266,688	77,527	45,913	2,093	392,222
11	72,343	36,353	108,697	18,987	12,598	2,047	142,328
12	84,122	44,672	128,793	19,417	11,773	1,975	161,958
13	118,978	56,093	175,072	25,825	14,343	1,998	217,238
14	130,185	83,663	213,848	47,770	25,065	2,575	289,258
16	470,033	292,588	762,622	158,665	109,625	2,058	1,032,970

Table 17

Three-Day Average of Suspended Size Distribution in Houston on February 5,6, and 15, 1973

## Percentage

Station	0.3-0.5 $\mu\text{m}$	0.5-0.7 $\mu\text{m}$	0.3-0.7 $\mu\text{m}$	0.7-1.4 $\mu\text{m}$	1.4-3.0 $\mu\text{m}$	3.0-10 $\mu\text{m}$
P1	44.67	32.82	77.49	13.74	7.77	1.01
2	52.93	27.74	80.67	11.34	6.78	1.20
3	46.78	28.49	75.28	13.80	9.48	1.45
4	39.75	28.26	68.00	19.58	11.70	0.72
5	45.51	26.65	72.15	15.37	11.30	1.18
7	52.05	25.19	77.24	13.05	8.43	1.27
8	42.36	31.65	74.01	17.18	8.25	0.56
9	47.05	25.44	72.50	15.18	10.42	1.91
10	38.87	29.13	67.99	19.77	11.71	0.53
11	50.83	25.54	76.37	13.34	8.85	1.44
12	51.94	27.58	79.52	11.99	7.27	1.22
13	54.77	25.82	80.59	11.89	6.60	0.92
14	45.01	28.92	73.93	16.51	8.67	0.89
16	45.50	28.32	73.83	15.36	10.61	0.20

Table 18 . Three-Day Average of Suspended Particulate Size Distribution in Houston on August 25, November 29, 1972 and February 15, 1973.

Number of Particles per m<sup>3</sup>

Station	0.3-0.5μm	0.5-0.7μm	0.3-0.7μm	0.7-1.4μm	1.4-3.0μm	3.0-10.0μm	0.3-10.0μm (Total)
P1	4,302,053	2,525,724	6,827,777	1,187,063	751,632	58,615	8,825,087
2	5,680,320	2,606,290	8,286,610	1,105,321	677,187	76,564	10,145,682
3	5,058,158	2,368,183	7,426,341	1,101,495	743,099	92,042	9,362,977
4	6,022,591	2,104,947	8,127,538	979,735	784,706	63,970	9,955,949
5	3,226,804	1,573,826	4,800,630	701,492	662,004	61,969	6,226,095
7	3,484,332	1,810,050	5,294,382	924,298	753,810	62,028	7,034,518
8	3,427,130	1,452,653	4,879,783	1,005,452	771,347	64,617	6,721,199
9	3,076,090	1,495,908	4,571,998	988,563	812,836	69,208	6,442,605
10	3,533,766	1,662,277	5,196,043	884,810	673,833	70,502	6,825,188
11	2,269,845	1,071,953	3,341,798	641,171	569,492	59,438	4,611,899
12	2,397,961	1,100,789	3,498,750	616,689	709,908	61,616	4,886,963
13	3,511,697	2,140,434	5,652,131	1,319,358	1,197,480	59,262	8,228,231
14	4,249,147	1,987,423	6,236,570	942,248	818,133	89,040	8,085,991
16	12,052,951	6,622,273	18,675,224	3,254,758	2,501,713	85,274	24,516,969

Table 19 . The Average of Suspended Particulate Size Distributions in Houston  
on August 23, 25, 28, November 29, December 1, 4, 1972, February  
5, 6, and 15, 1973.

Number of Particles per m<sup>3</sup>

Station	0.3-0.5μm	0.5-0.7μm	0.3-0.7μm	0.7-1.4μm	1.4-3.0μm	3.0-10.0μm	0.3-10.0μm (Total)
P1	6,545,846	3,320,808	9,866,654	1,576,278	804,362	82,312	12,329,606
2	21,022,495	8,622,722	29,645,217	2,222,058	1,349,823	157,012	33,374,110
3	7,974,901	3,788,901	11,763,802	1,889,085	921,924	110,756	14,685,567
4	7,468,791	3,790,990	11,259,781	2,396,784	1,254,770	82,478	14,993,813
5	6,320,911	2,834,344	9,155,256	1,537,859	910,892	52,588	11,656,594
7	6,684,776	3,225,578	9,910,354	1,762,901	982,932	99,908	12,756,095
8	6,507,643	3,625,337	10,132,980	2,060,221	1,084,311	78,800	13,356,312
9	4,282,897	2,073,953	6,356,850	1,102,623	491,427	66,285	8,017,185
10	6,141,880	3,656,370	9,798,250	2,028,638	1,072,404	81,154	12,980,446
11	4,405,923	2,149,810	6,555,733	1,102,712	641,799	78,408	8,378,652
12	4,123,384	2,100,023	6,223,407	909,786	600,564	83,410	7,817,161
13	5,007,939	2,652,899	7,660,838	1,261,156	794,840	75,289	9,792,123
14	8,622,682	4,829,819	13,452,501	2,225,472	1,413,651	288,698	17,380,322
16	13,640,998	7,776,871	21,417,869	3,827,270	2,555,169	88,824	27,889,132

TABLE 20

Suspended Particulate Mass Concentration Data in Houston  
on August 19, 25, and 31, 1972

$\mu\text{g}/\text{m}^3$

Station	Aug. 19	Aug. 25	Aug. 31	Average
P1	89.6	69.8	165.8	108.4
2	92.5	89.9	165.3	115.9
3	109.9	62.0	160.5	110.8
4	52.2	42.9	134.7	76.6
5	86.4	52.6	121.0	86.7
6	74.1	42.5	147.6	88.1
7	92.6	Void	142.4	117.5
8	46.4	38.4	100.5	61.8
9	95.2	52.6	129.5	92.4
10	65.3	47.8	99.9	71.0
11	61.3	59.7	Void	60.5
12	71.2	66.5	104.7	80.8
13	95.3	100.8	96.1	97.4
14	102.5	67.3	125.8	98.5
16	93.1	160.9	118.3	124.1

Table 21

Suspended Particulate Mass Concentration Data in  
Houston on November 29, and December 5, 1972

$\mu\text{g}/\text{m}^3$

Station	Nov. 29	Dec. 5	Average
P1	80.8	94.0	87.4
2	88.6	81.2	84.9
3	96.2	64.6	80.4
4	32.3	56.5	44.4
5	160.3	69.0	114.7
6	64.8	55.2	60.0
7	55.2	94.1	74.7
9	67.1	71.9	69.5
10	46.5	60.7	53.6
11	40.6	41.3	41.0
12	29.7	44.9	37.3
13	64.6	49.9	57.3
15	28.0	82.8	55.4
16	34.4	163.1	98.8
DP	58.3	48.2	53.3

Table 22

Suspended Particulate Mass Concentration Data in  
Houston on February 9, and 15, 1973.

$\mu\text{g}/\text{m}^3$

Station	February 9	February 15	Average
P1	63.7	98.5	81.1
2	91.3	118.6	104.9
3	39.4	126.8	83.1
4	28.5	64.9	46.7
5	25.2	105.9	52.9
6	44.1	116.0	46
7	29.0	59.7	44.4
8	22.4	41.6	32
9	31.6	66.8	49.2
10	28.3	75.8	52.1
11	20.9	46.4	33.7
12	25.2	61.9	43.6
13	37.1	66.4	51.8
14	49.4	94.8	72.1
15	37.3	59.5	48.4
16	27.5	48.8	38.2
DP	41.3	103.6	72.5

features of geographic significance. Then coordinates are established in order to locate the sampling stations in the area concerned. Finally the sampling data of each station is introduced. The SYMAP computer program consists of instruction for the trend-surface calculation, isopleths divisions, and printing of the maps.

The data in Tables 6, 7, 10, 11, 14, 15, 18, 19, 20, 21, and 22 was used as input data. The resulting isopleth maps were shown in Figures 15-62.

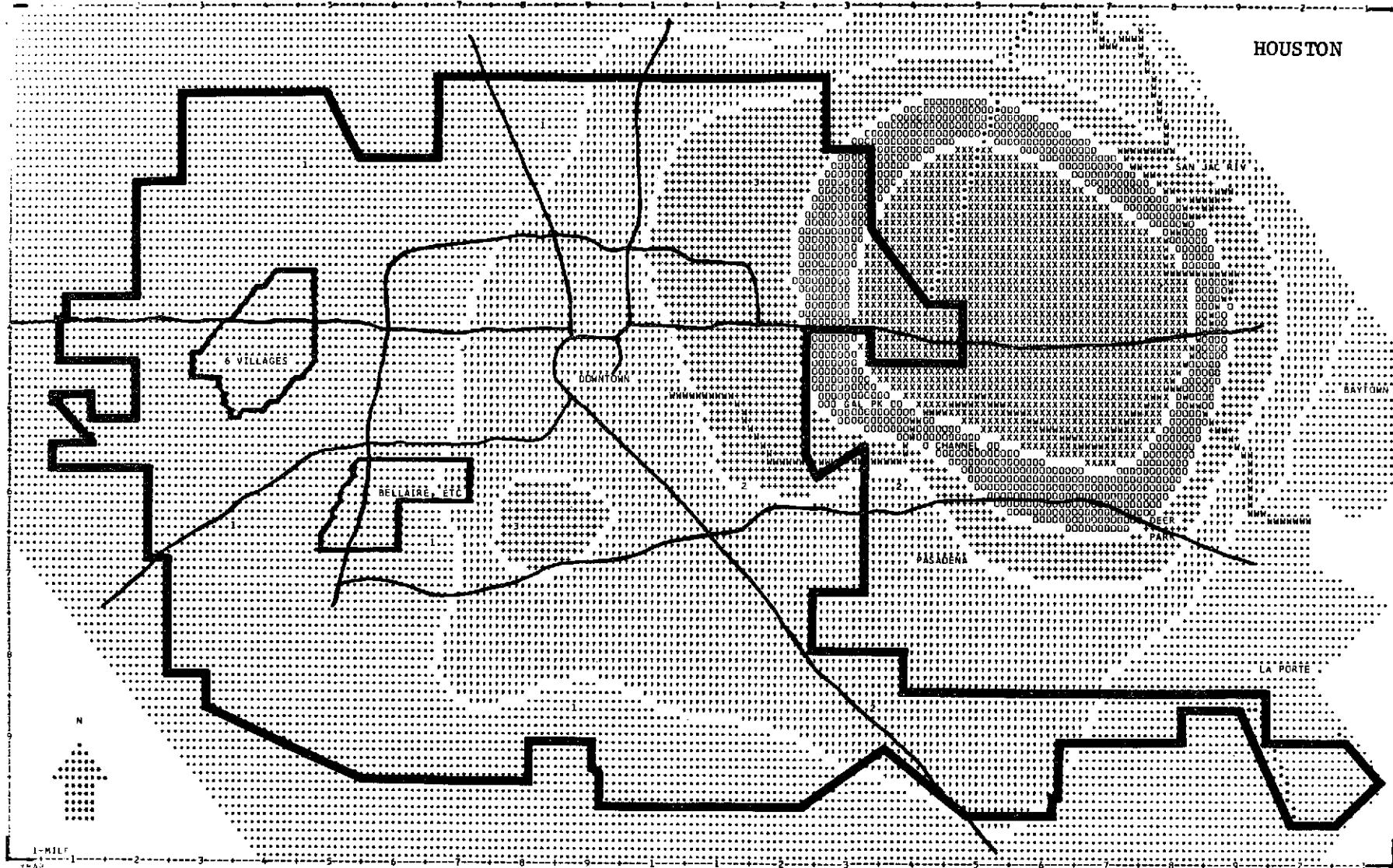


Figure 15. Suspended Particulate Size Distribution  
 0.3 - 0.7  $\mu\text{m}$ , August 25, 1972  
 Unit: Number  $\times 1,000/\text{m}^3$   
 (2,500,000/ $\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	3,549	6,645	12,839	25,226	50,000
Minimum	2,000	3,549	6,645	12,839	25,226
Symbol	.....	,,,,	+++	000000	xxxxxx
Frequency	15	4	3	0	1

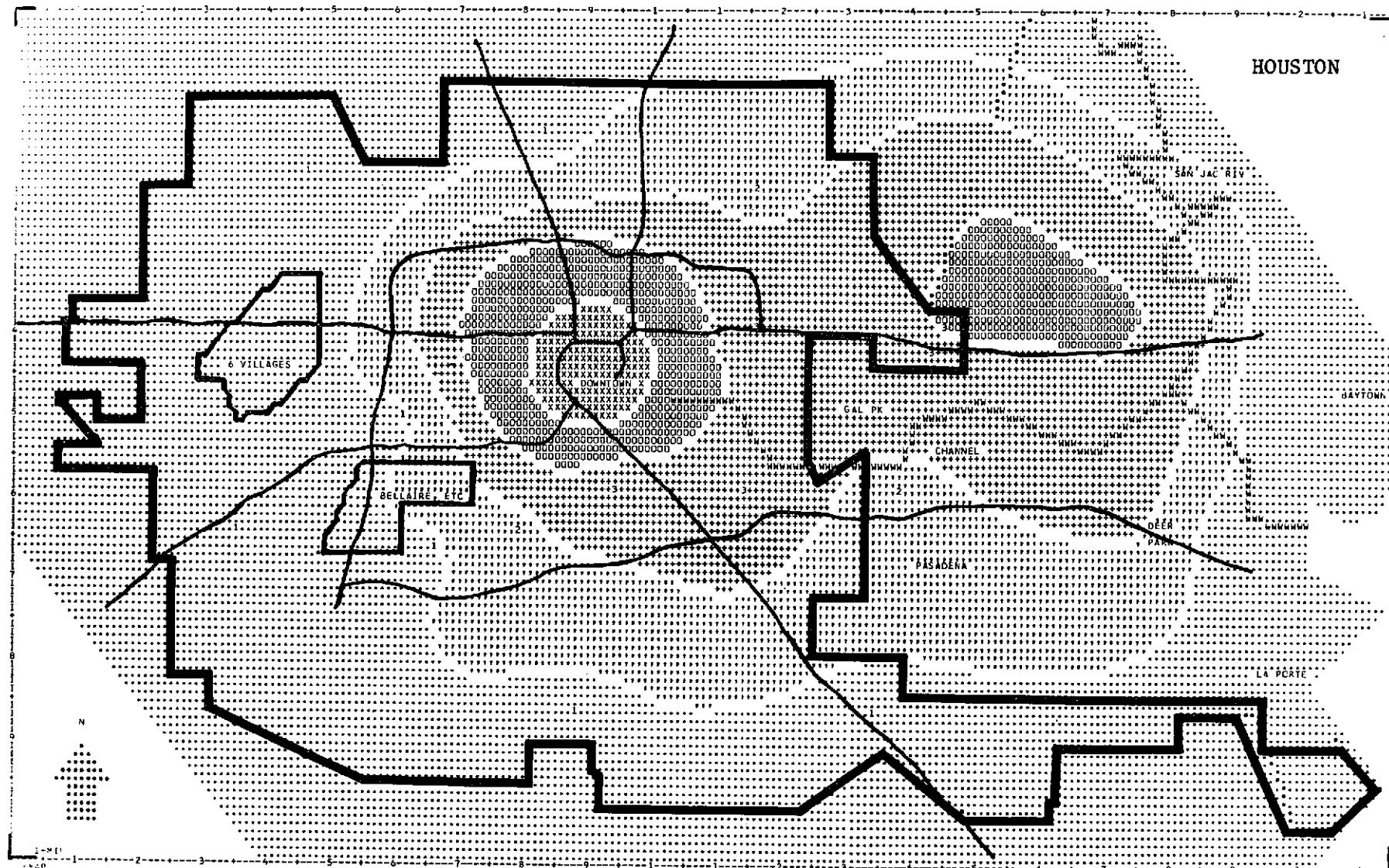


Figure 16 Suspended Particulate Size Distribution  
 $0.3 - 0.7 \mu\text{m}$ , 3-Day Average  
 August 23, 25, 28, 1972  
 Unit: Number  $\times 1,000/\text{m}^3$   
 $(4,000,000/\text{m}^3$  - Assumed Background)

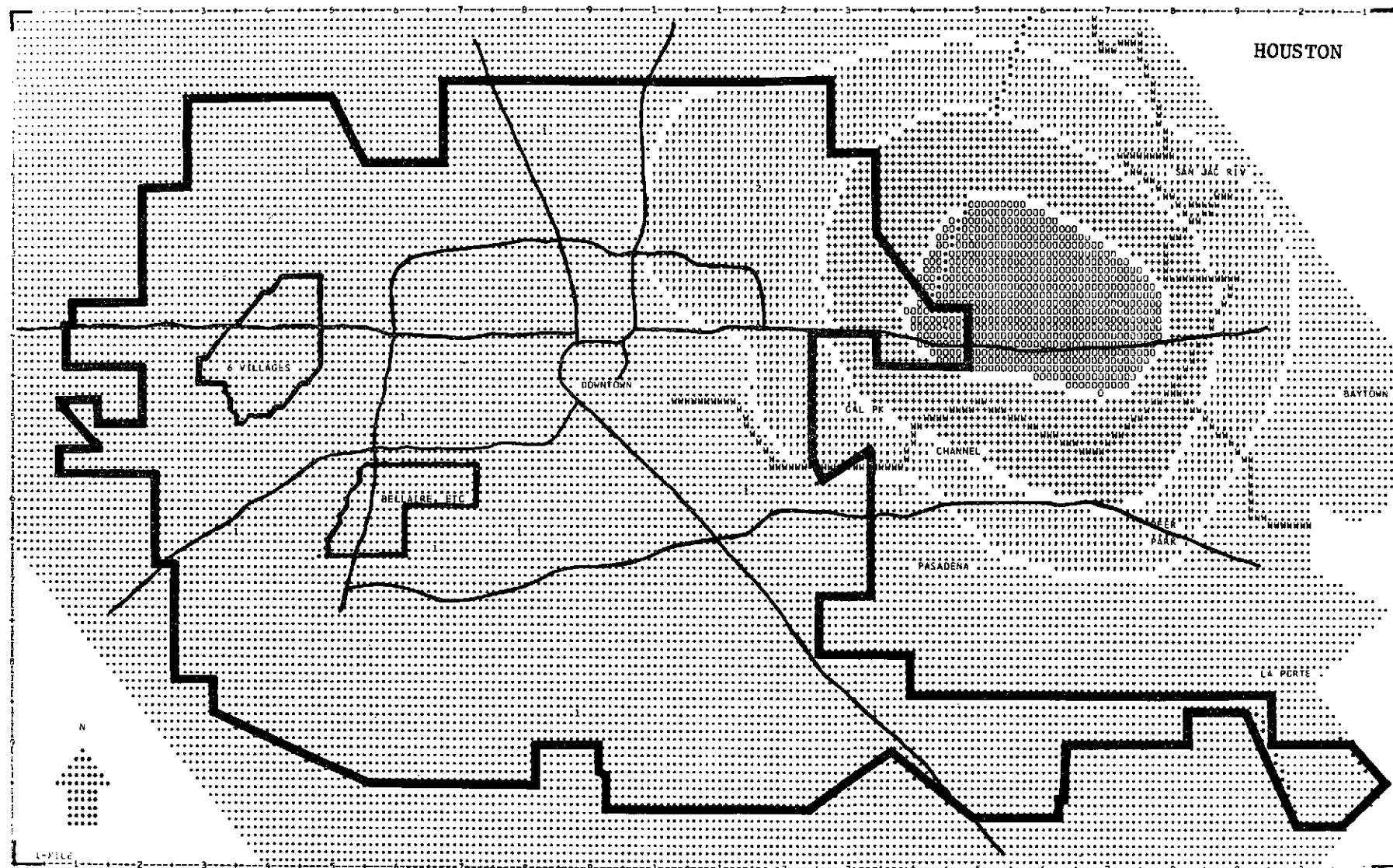


Figure 17. Suspended Particulate Size Distribution  
 0.7 - 1.4  $\mu\text{m}$ , August 25, 1972  
 Unit: Number  $\times 1,000/\text{m}^3$   
 $(1,250,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	2,000	4,000	8,000	16,000	32,000
Minimum	1,000	2,000	4,000	8,000	16,000
Symbol	....	. , , ,	+ + +	000000	xxxxxx
Frequency	20	2	0	1	0

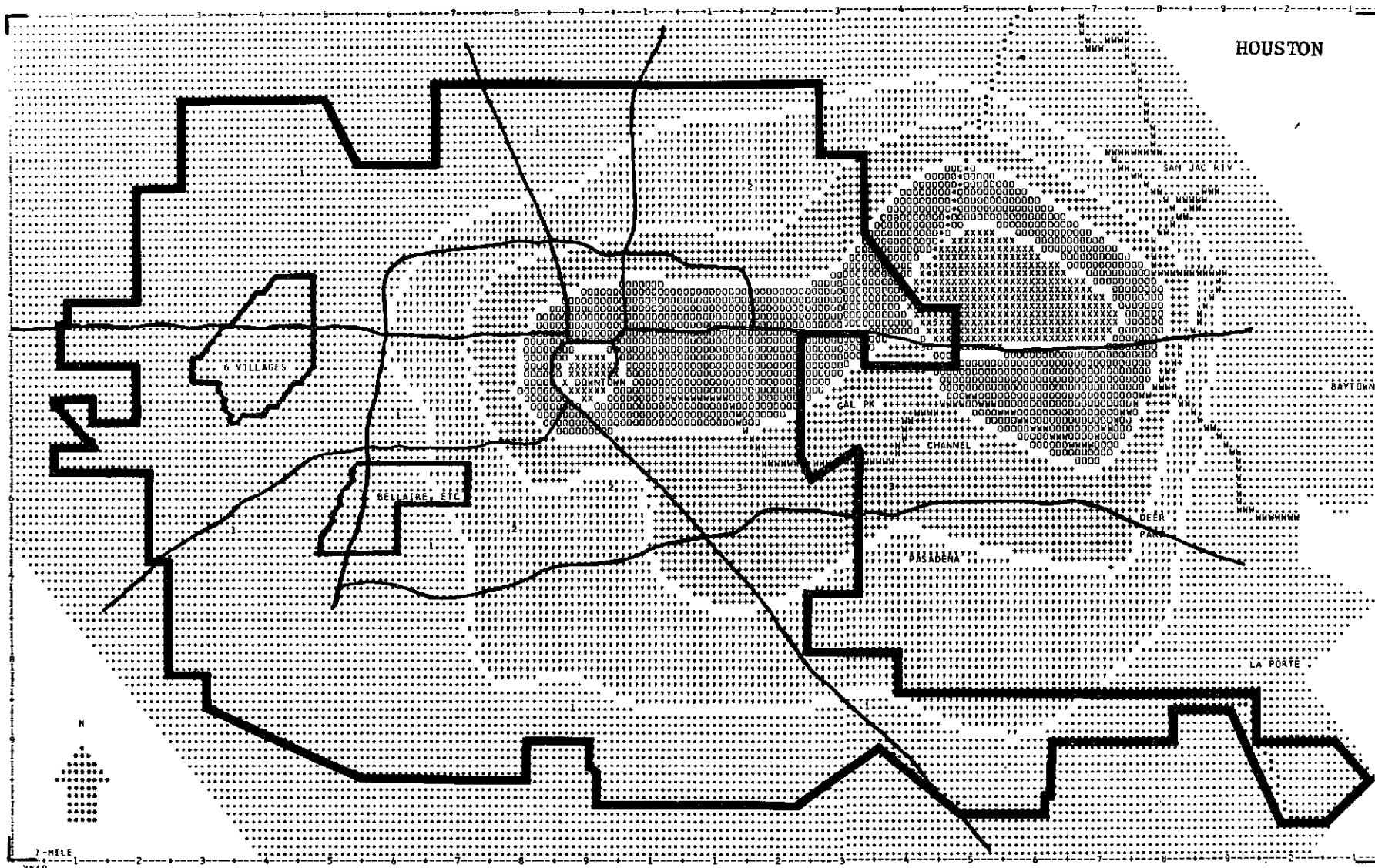


Figure 18. Suspended Particulate Size Distribution  
 0.7 - 1.4  $\mu\text{m}$ , 3-Day Average,  
 August 23, 25, 28, 1972,  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 $(600,000/\text{m}^3$  -Assumed Background)

Level	1	2	3	4	5
Maximum	1,160	1,920	2,680,	3,440	4,200
Mimimum	400	1,160	1,920	2,680	3,440
Symbol	.....	,....	+ + +	00000	xxxxx
Frequency	16	3	3	1	2

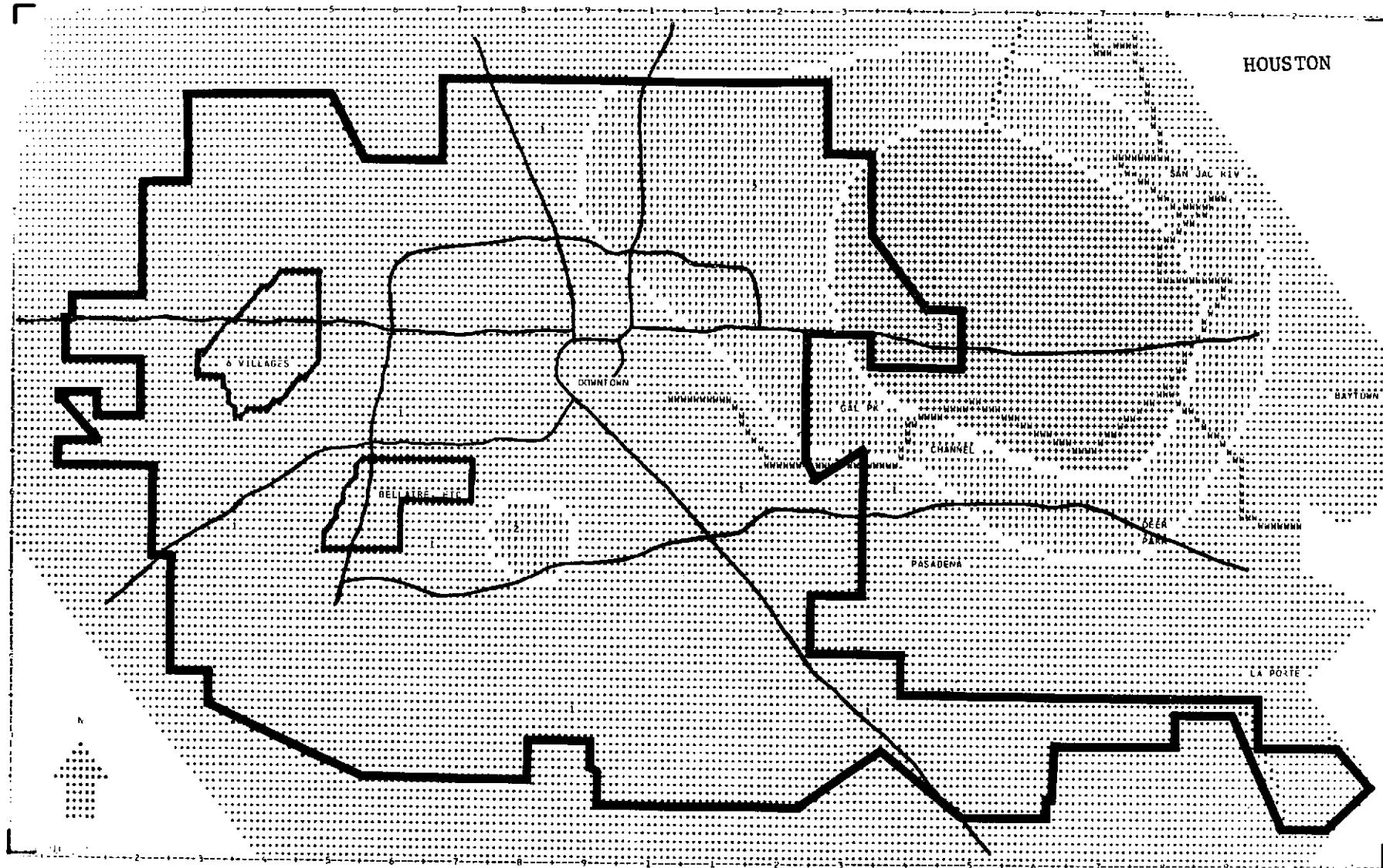


Figure 19. Suspended Particulate Size Distribution  
 1.4 - 3.0  $\mu\text{m}$ , August 25, 1972  
 Unit: Number  $\times 1,000/\text{m}^3$   
 $(1,250,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	2,000	4,000	8,000	16,000	32,000
Minimum	1,000	2,000	4,000	8,000	16,000
Symbol	.....	.....	+ + +	000000	XXXXXX
Frequency	19	3	1	0	0

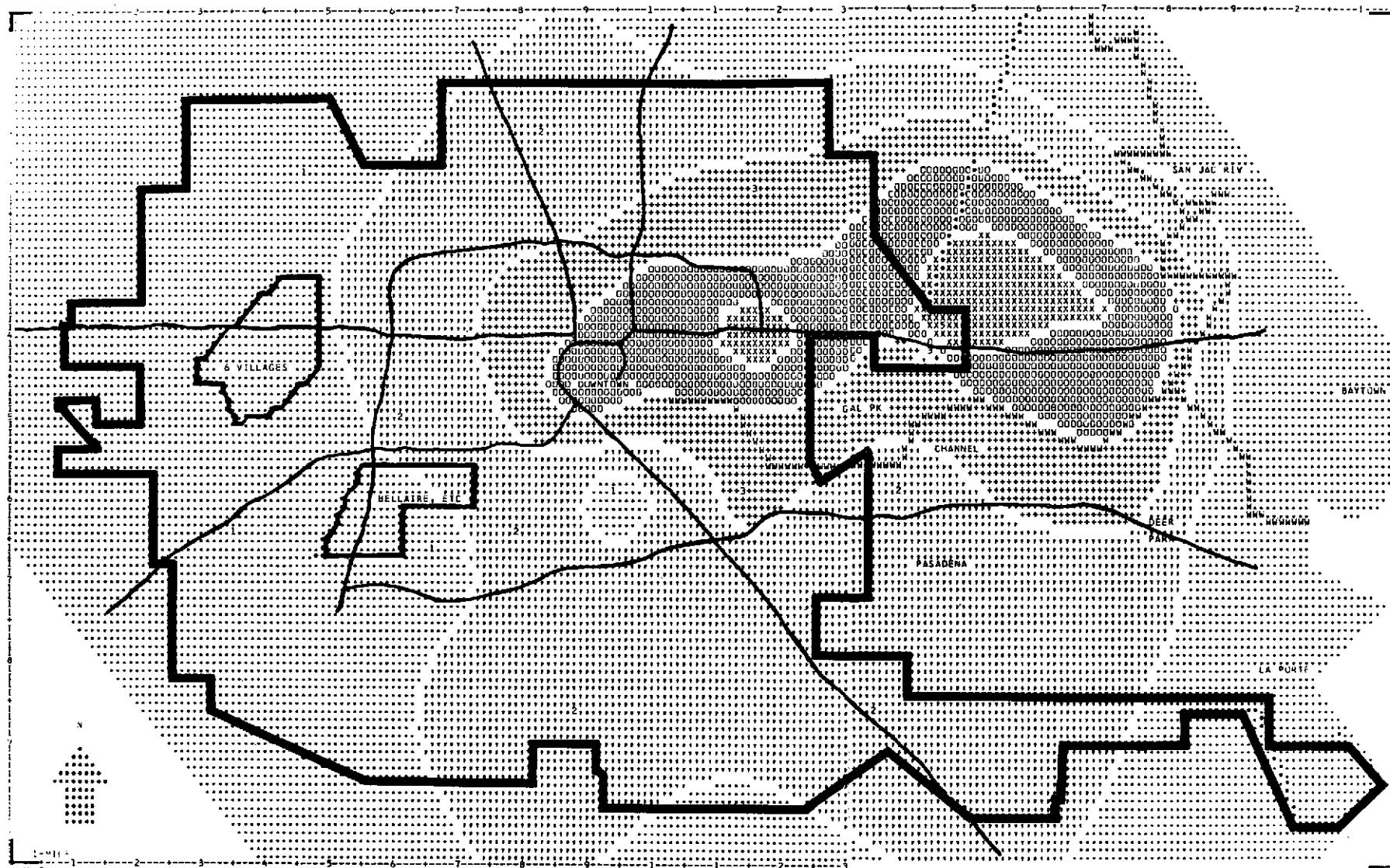


Figure 20. Suspended Particulate Size Distribution  
 1.4 - 3.0  $\mu\text{m}$ , 3-Day Average  
 August 23, 25, 28, 1972  
 Unit: Number  $\times 1,000/\text{m}^3$   
 $(600,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	900	1,500	2,100	2,700	3,300
Minimum	300	900	1,500	2,100	2,700
Symbol	...	, , , ,	+++	00000	xxxxx
Frequency	13	6	3	1	2

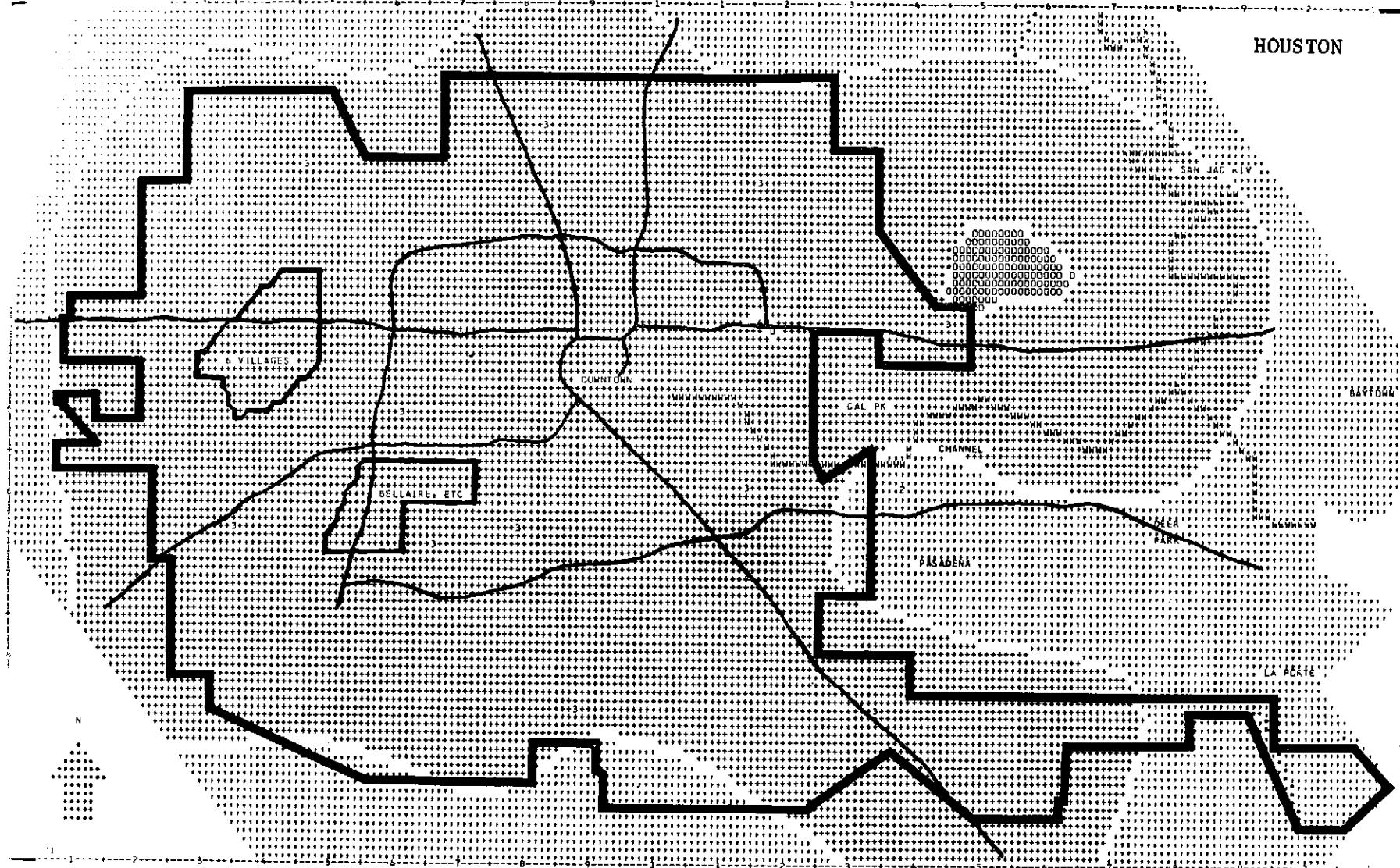


Figure 21. Suspended Particulate Size Distribution  
 3.0 - 10.0  $\mu\text{m}$ , August 25, 1973  
 Unit: Number  $\times 1,000/\text{m}^3$   
 $(100,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	60	120	240	480	960
Minimum	30	60	120	240	480
Symbol	...	,,	+++	0000	xxxx
Frequency	0	10	12	1	0

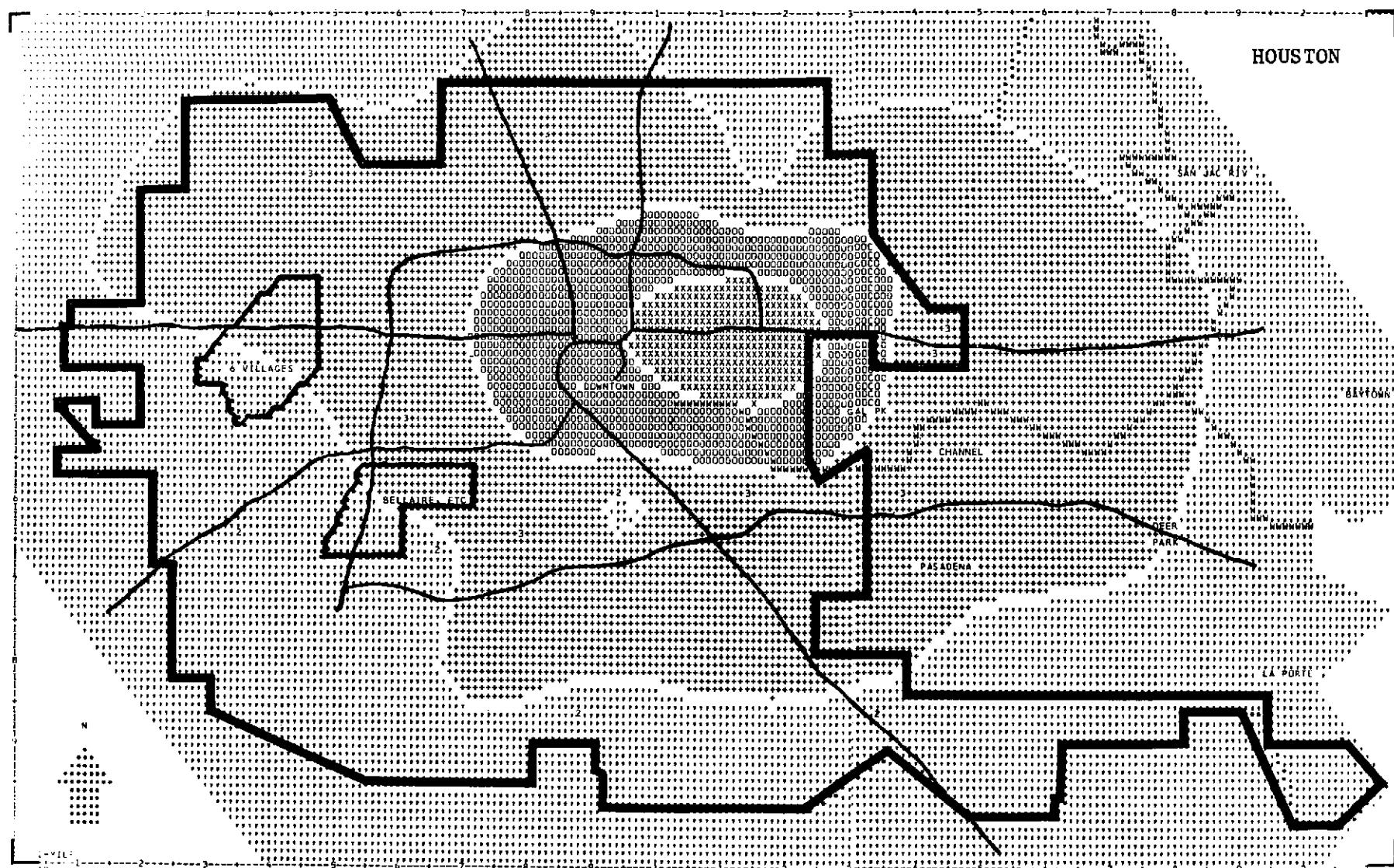


Figure 22. Suspended Particulate Size Distribution,  
3.0 - 10.0  $\mu\text{m}$ , 3-Day Average  
August 23, 25, 28, 1972  
Unit: Number  $\times 1,000/\text{m}^3$   
( $100,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	60	120	240	480	960
Minimum	30	60	120	240	480
Symbol	....	,,	++	00000	xxxxx
Frequency	0	14	9	1	1

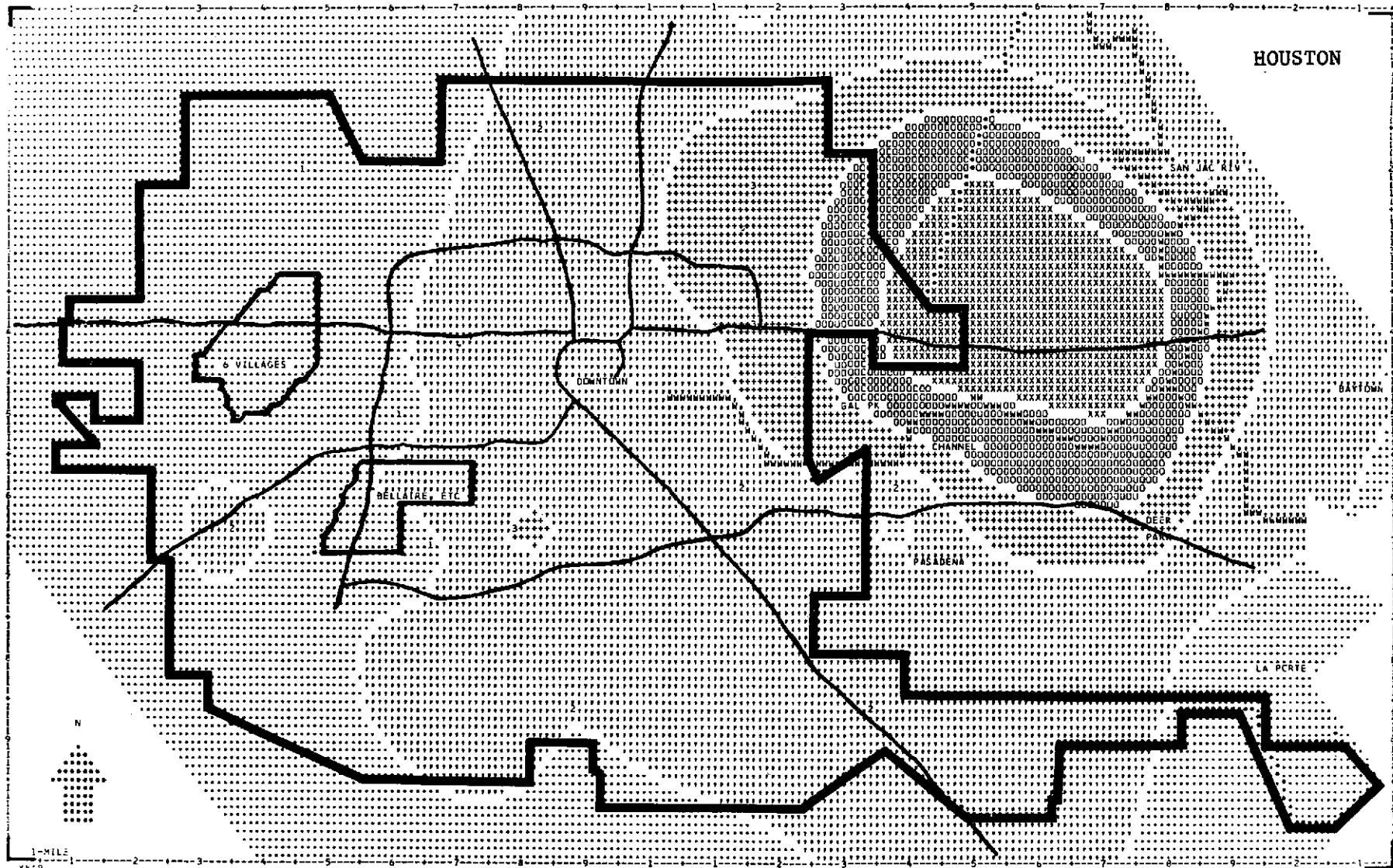


Figure 23. Suspended Particulate Size Distribution  
 0.3 - 10.0  $\mu\text{m}$ , August 25, 1972  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 $(3,600,000/\text{m}^3$  - Assumed Background)

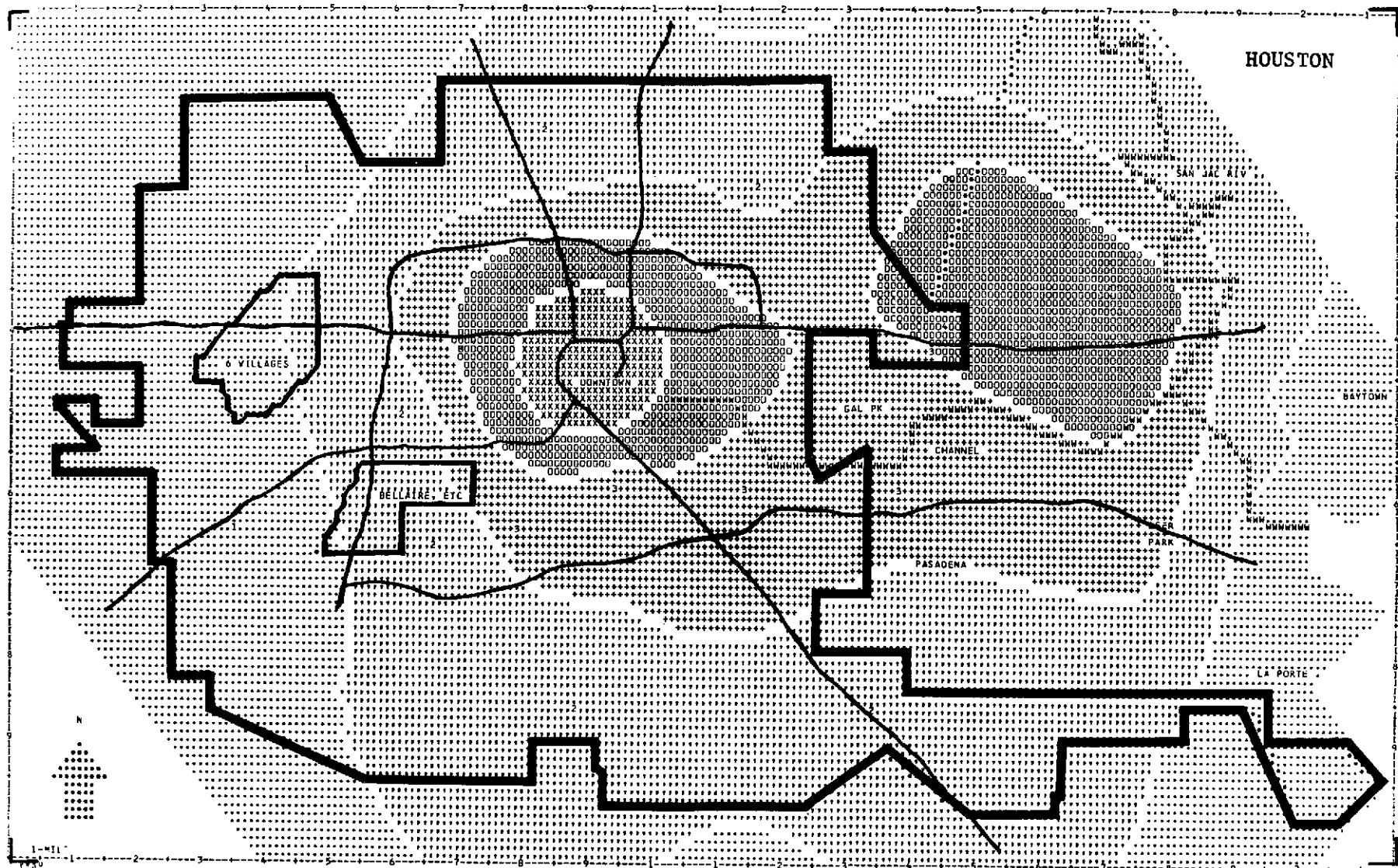


Figure 24. Suspended Particulate Size Distribution  
 $0.3 - 10.0 \mu\text{m}$ , 3-Day Average  
 August 23, 25, 28, 1972  
 $(5,600,000/\text{m}^3 - \text{Assumed Background})$

Level	1	2	3	4	5
Maximum	6,000	12,000	24,000	48,000	96,000
Minimum	3,000	6,000	12,000	24,000	48,000
Symbol	.....	.....	+++	0000000	xxxxxx
Frequency	11	6	5	2	1

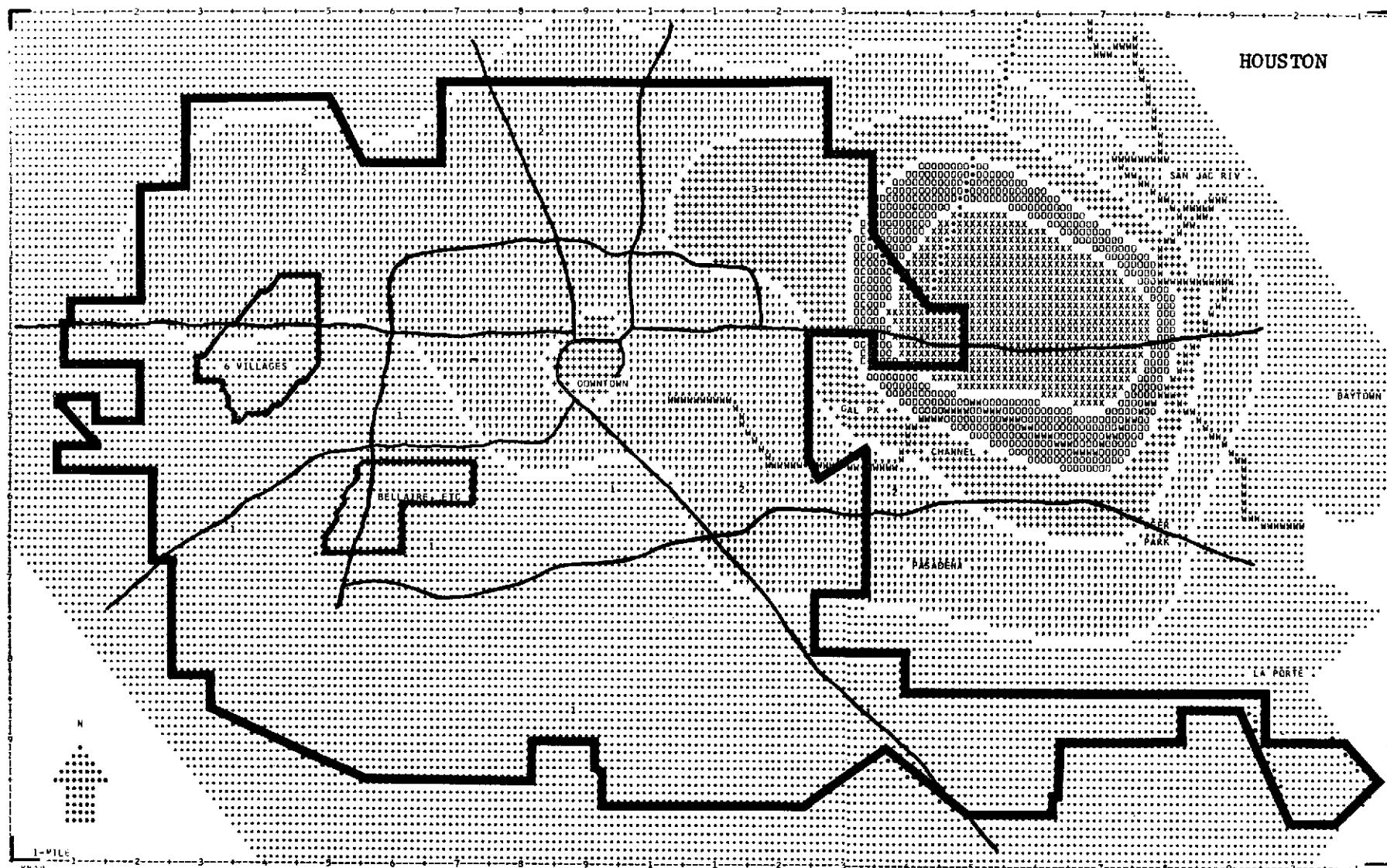


Figure 25. Suspended Particulate Matter 3-Day,  
24-HR Average, August 25, 1972  
Unit:  $\mu\text{g}/\text{m}^3$   
(40  $\mu\text{g}/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	55	85	115	145	175
Minimum	25	55	85	115	145
Symbol	...	,,	++	00000	xxxx
Frequency	15	5	2	0	1

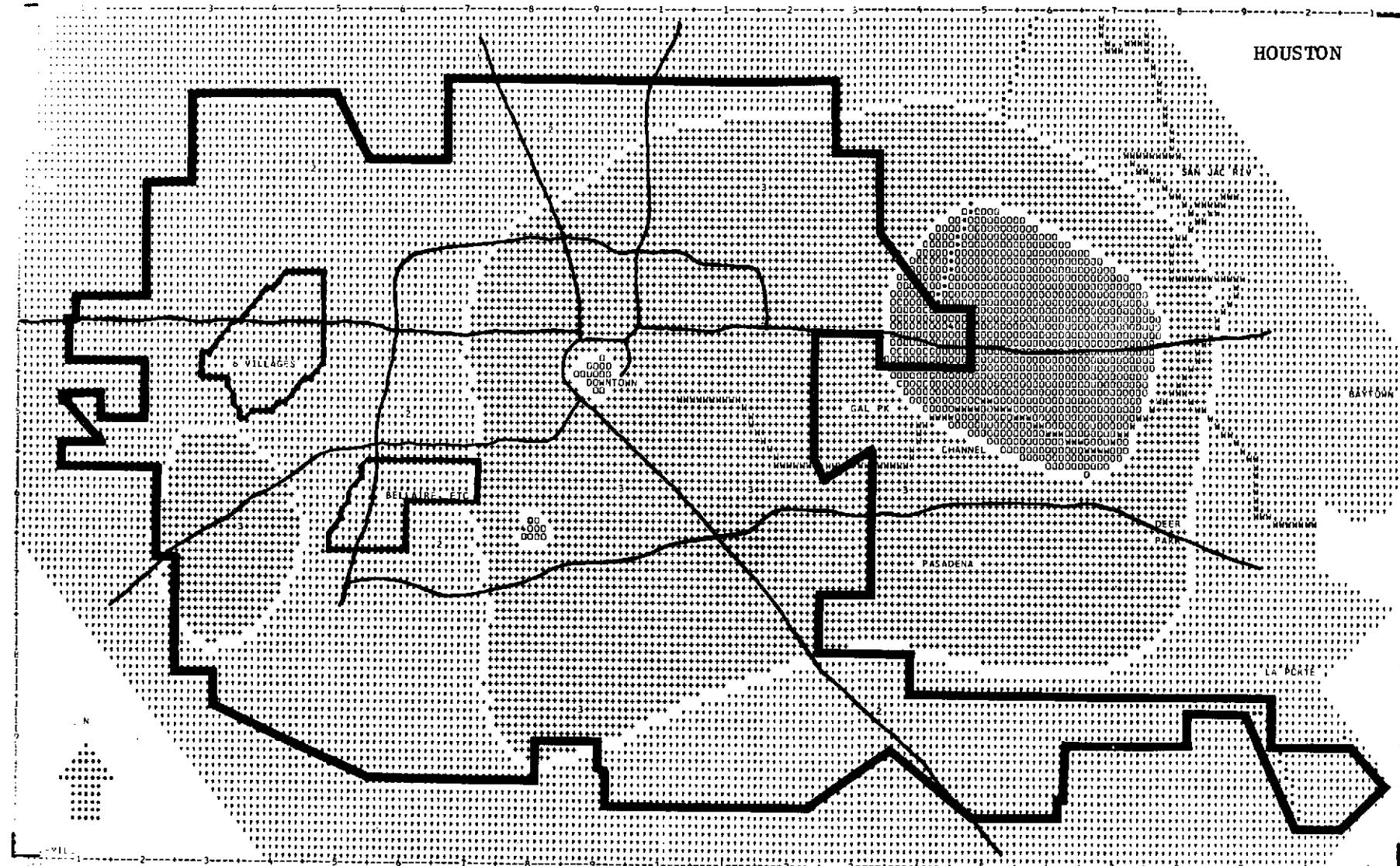


Figure 26. Suspended Particulate Matter  
3-Day, 24-HR Average,  
August 19, 25, and 31, 1972  
Unit:  $\mu\text{g}/\text{m}^3$   
( $65 \mu\text{g}/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	55	85	115	145	175
Minimum	25	55	85	115	145
Symbol	.....	.....	+++	00000	xxxxx
Frequency	0	14	7	3	0

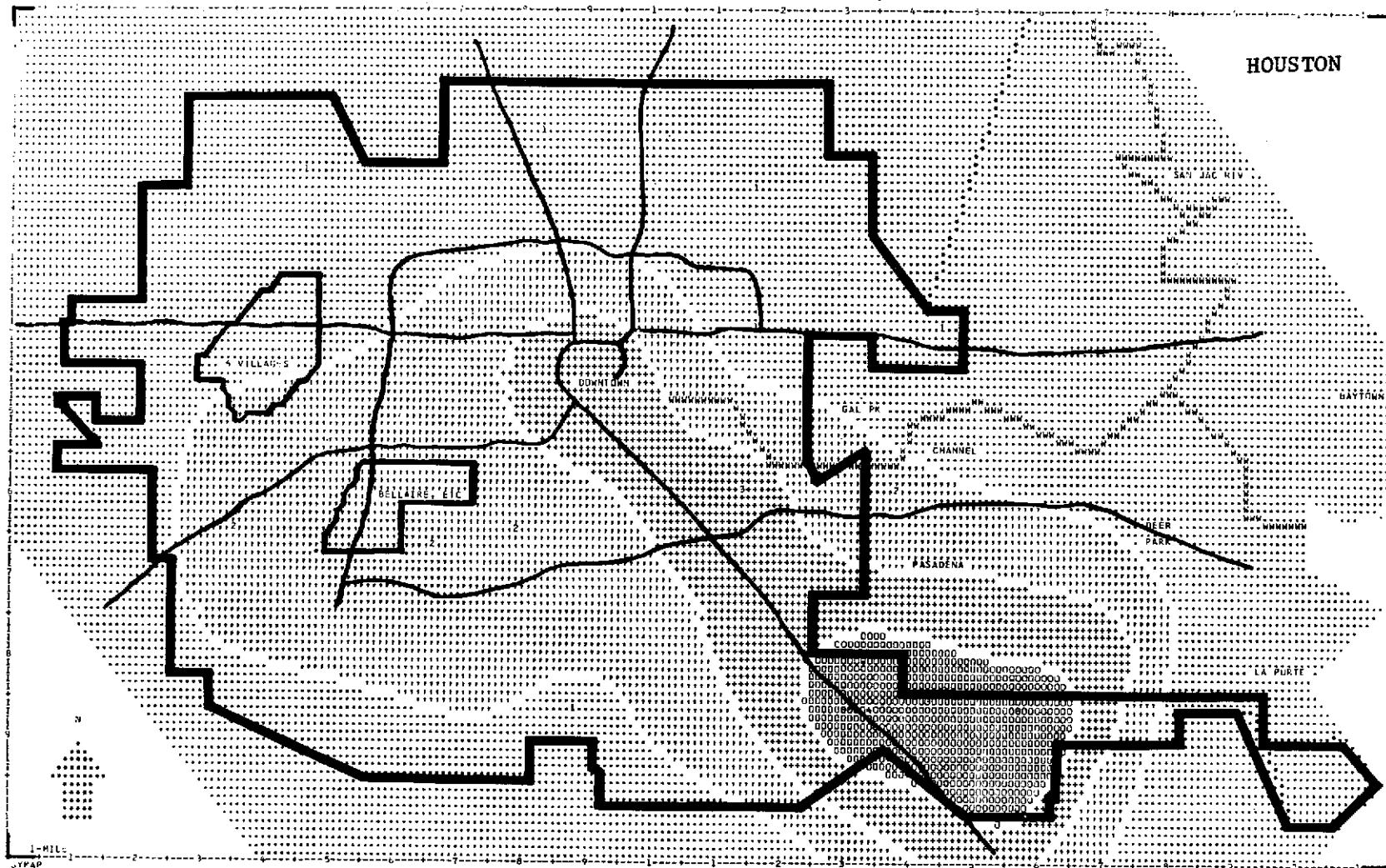


Figure 27. Suspended Particulate Size Distribution  
 $0.3 - 0.7 \mu\text{m}$ , November 29, 1972  
 Unit: Number  $\times 1,000/\text{m}^3$   
 $(3,200,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	6,800	10,600	14,400	18,200	22,000
Minimum	3,000	6,800	10,600	14,400	18,200
Symbol	.....	,, , ,	++ + +	0000000	xxxxxxx
Frequency	15	5	2	1	0

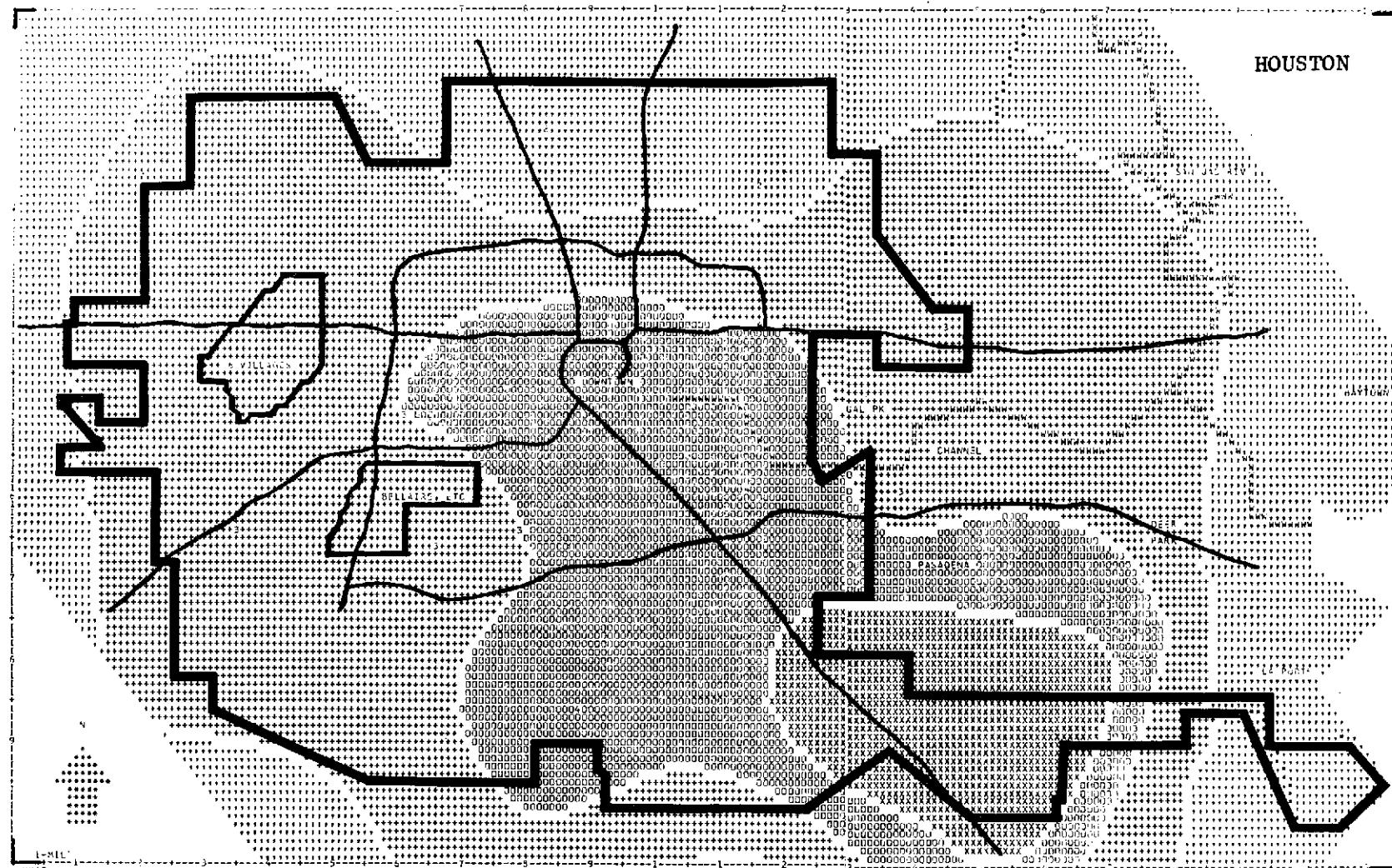


Figure 28. Suspended Particulate Size Distribution  
 0.3 - 0.7  $\mu\text{m}$ , 3-Day Average,  
 November 29, December 1, and 4, 1972  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 $(9,500,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	6,800	10,600	14,400	18,200	22,000
Minimum	3,000	6,800	10,600	14,400	18,200
Symbol	.....	, , , ,	++ +	000000000	xxxxxx
Frequency	0	11	7	4	1

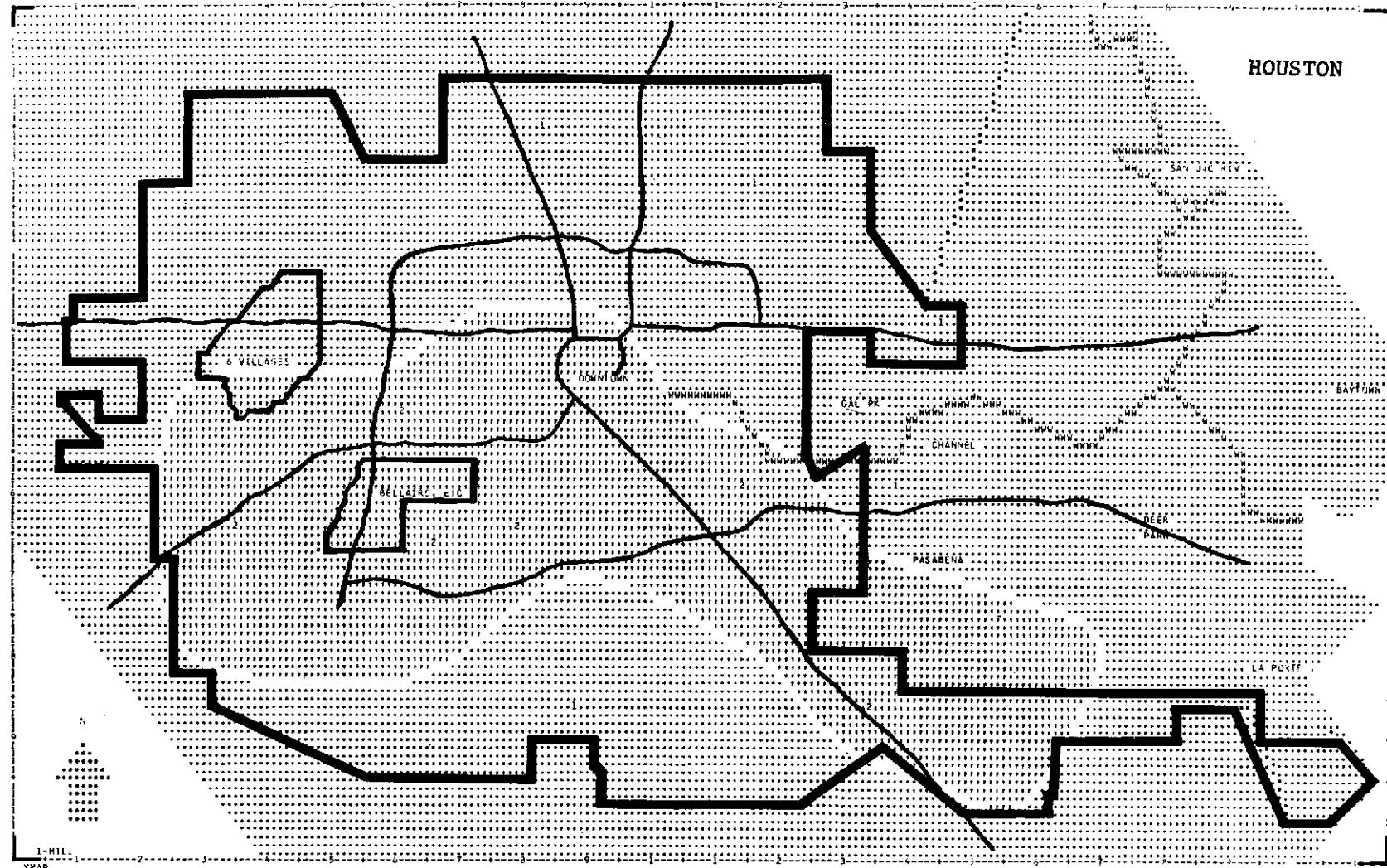


Figure 29. Suspended Particulate Size Distribution  
 0.7 - 1.4  $\mu\text{m}$ , November 29, 1972  
 Unit: Number  $\times 1,000/\text{m}^3$   
 (350,000/ $\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	1,080	1,860	2,640	3,420	4,200
Minimum	300	1,060	1,860	2,640	3,420
Symbol	.....	.....	+++	000000	xxxxxx
Frequency	16	7	0	0	0

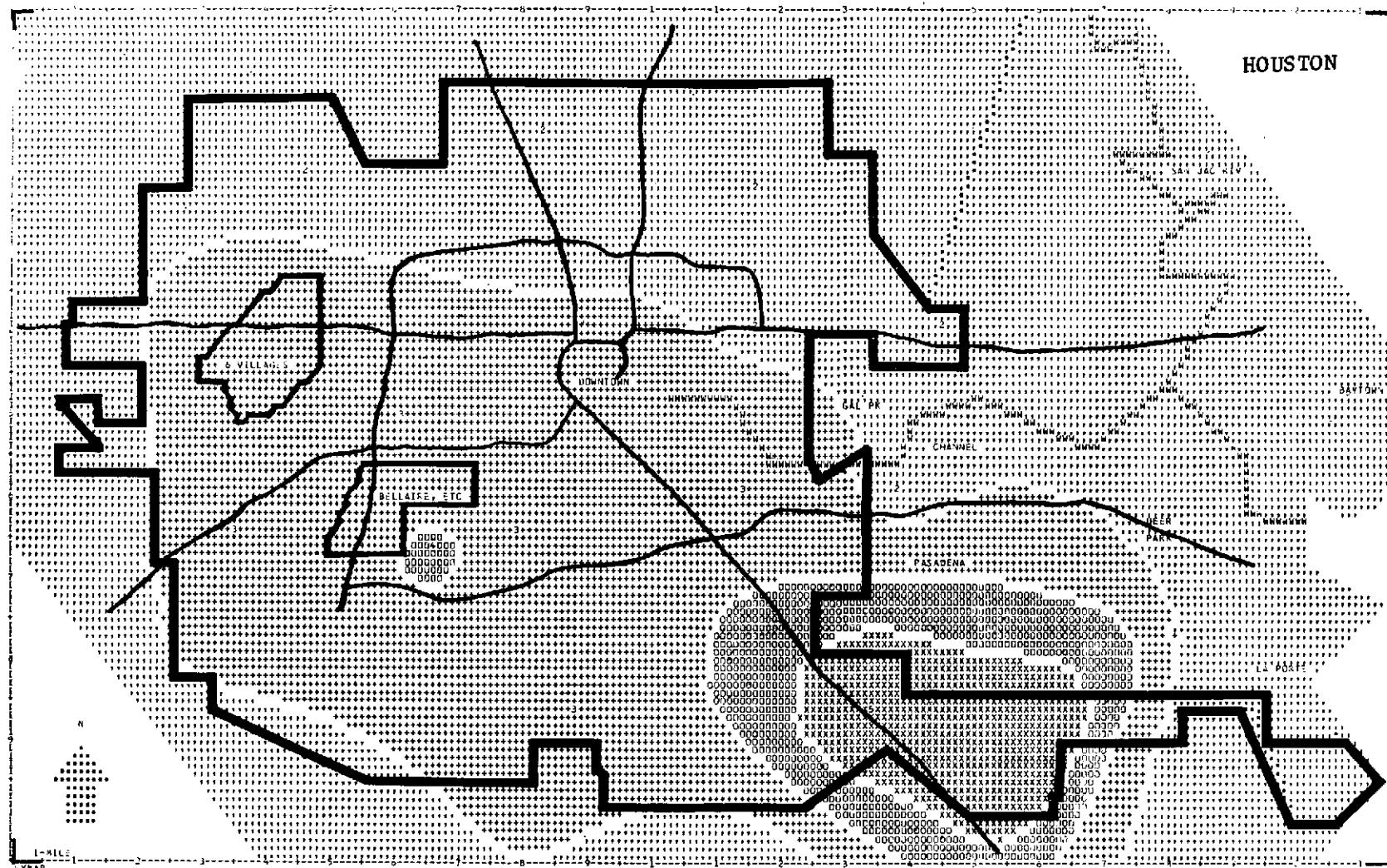


Figure 30. Suspended Particulate Size Distribution  
 0.7 - 1.4  $\mu\text{m}$ , 3-Day Average,  
 November 29, December 1, and 4, 1972  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 $(1,200,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	1,080	1,860	2,640	3,420	4,200
Minimum	300	1,080	1,860	2,640	3,420
Symbol	.....	,,,,	+++	000000	xxxxxx
Frequency	0	15	6	1	1

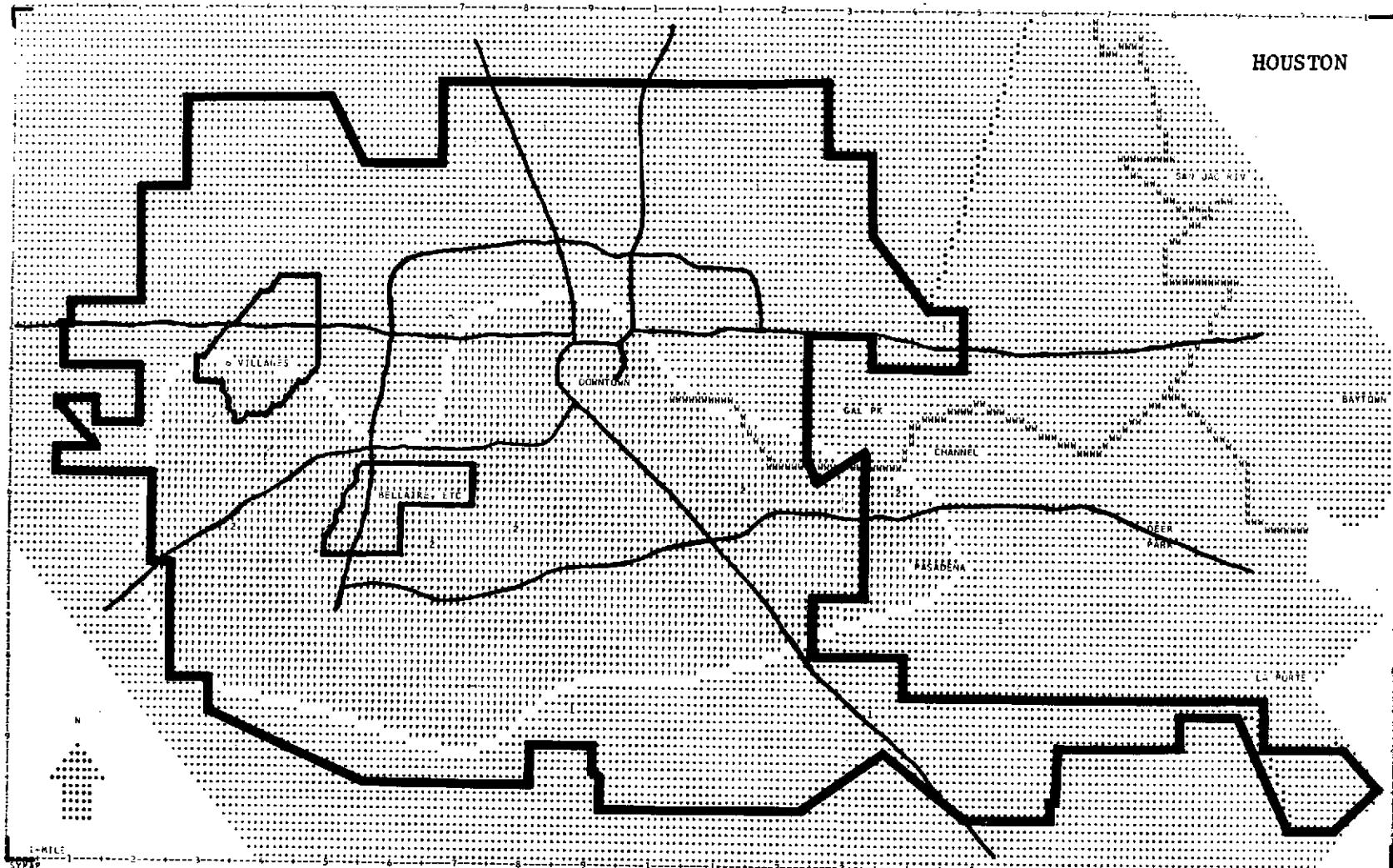


Figure 31. Suspended Particulate Size Distribution  
 1.4 - 3.0  $\mu\text{m}$ , November 29, 1972  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 $(120,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	360	620	880	1,140	1,400
Minimum	100	360	620	880	1,140
Symbol	.....	.....	+++	000000	xxxxx
Frequency	17	6	0	0	0

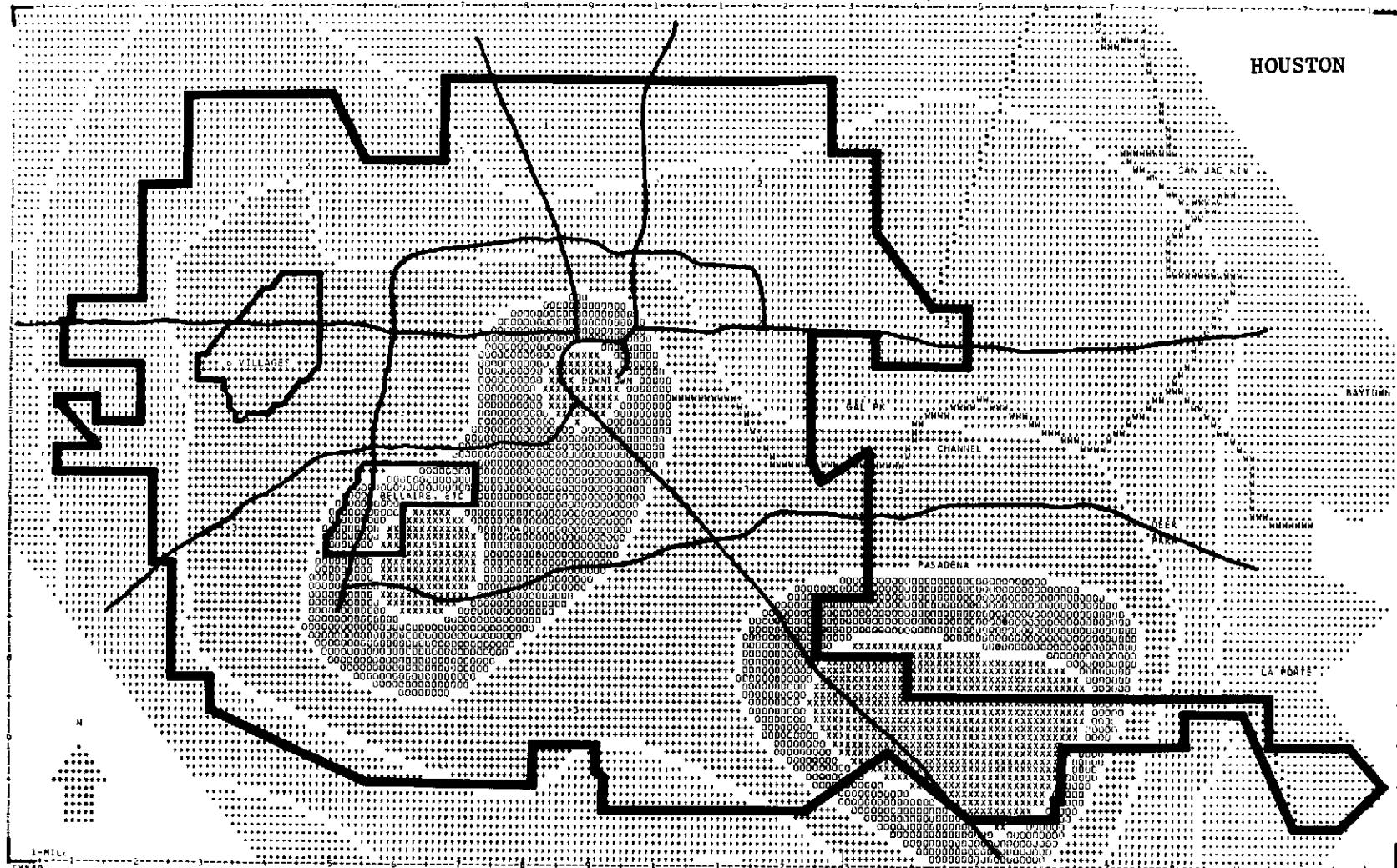


Figure 32. Suspended Particulate Size Distribution  
 1.4 - 3.0  $\mu\text{m}$ , 3-Day Average  
 November 29, December 1, and 4, 1972  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 (13,000/ $\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	360	620	880	1,140	1,400
Minimum	100	360	620	880	1,140
Symbol	....	.....	+++	000000	xxxxxx
Frequency	10	4	5	1	3

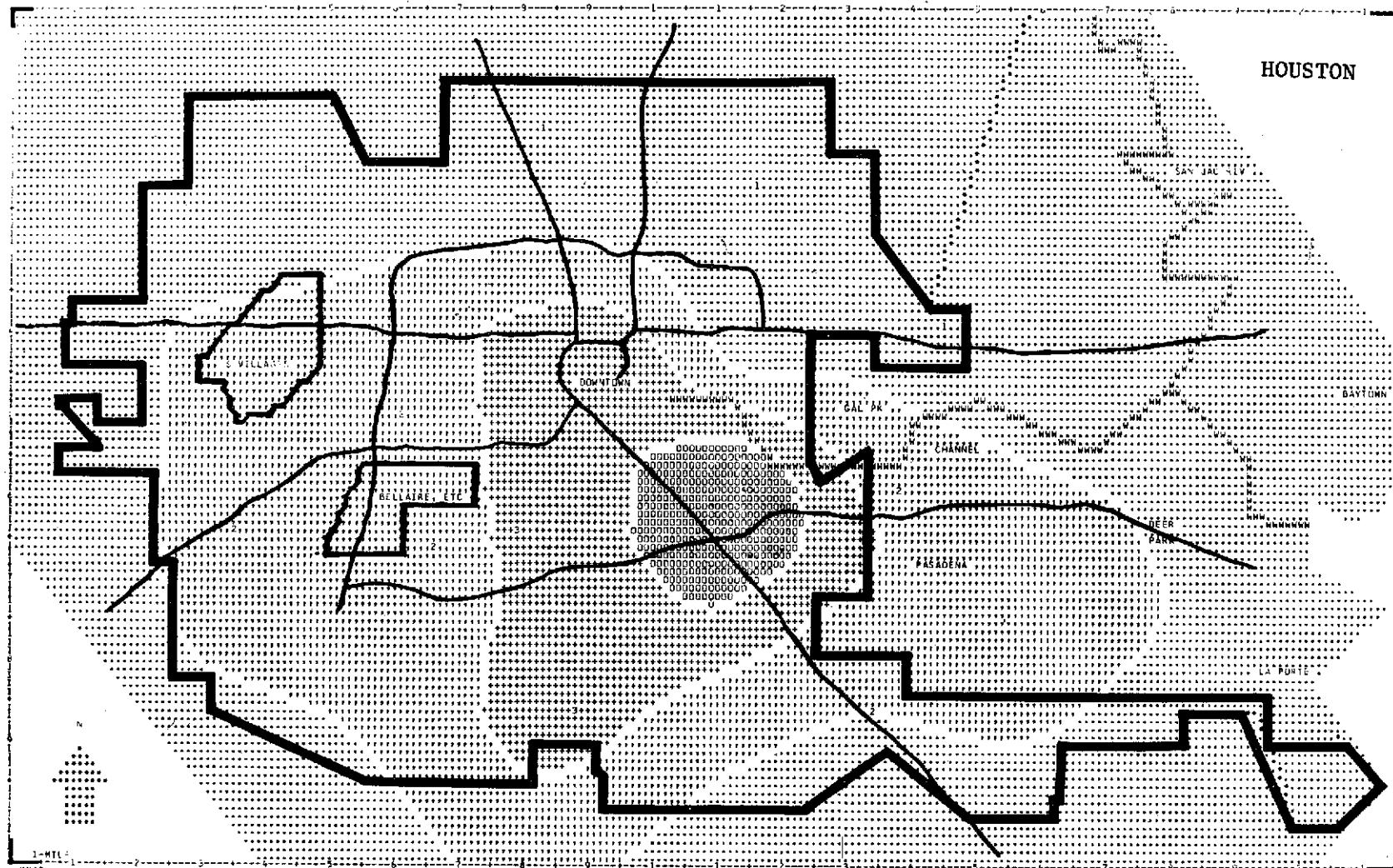


Figure 33. Suspended Particulate Size Distribution  
 3.0 - 10.0  $\mu\text{m}$ , November 29, 1972  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 (13,000/ $\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	28	46	64	82	100
Minimum	10	28	46	64	82
Symbol	....	, , ,	+++	00000	xxxxx
Frequency	14	5	3	1	0

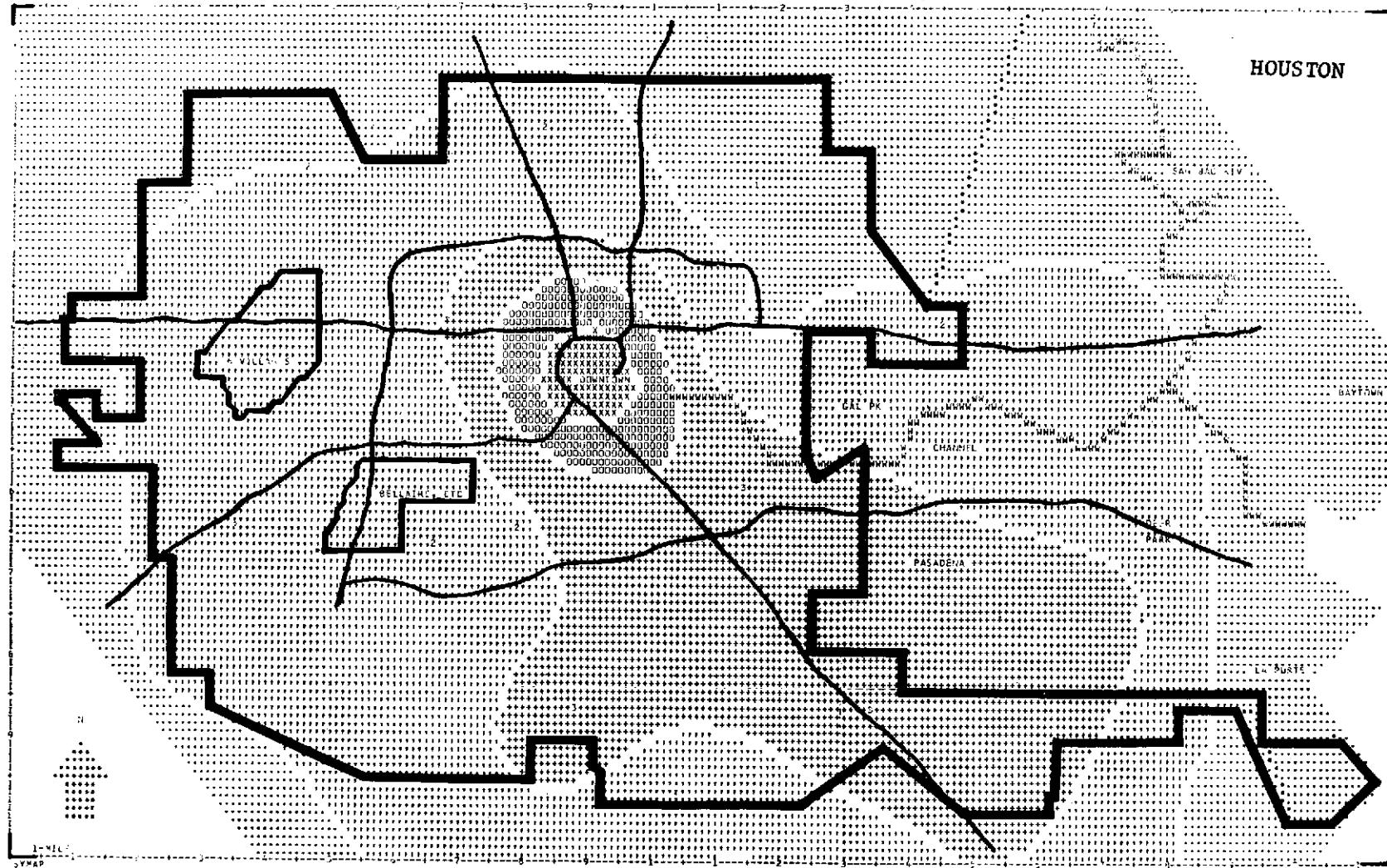


Figure 34. Suspended Particulate Size Distribution  
 3.0 - 10.0  $\mu\text{m}$ , 3-Day Average,  
 November 29, December 1, and 4, 1972  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 $(25,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	28	46	64	82	100
Minimum	10	28	46	64	82
Symbol	....	,,,,	+ + +	00000	xxxxx
Frequency	10	8	4	0	1

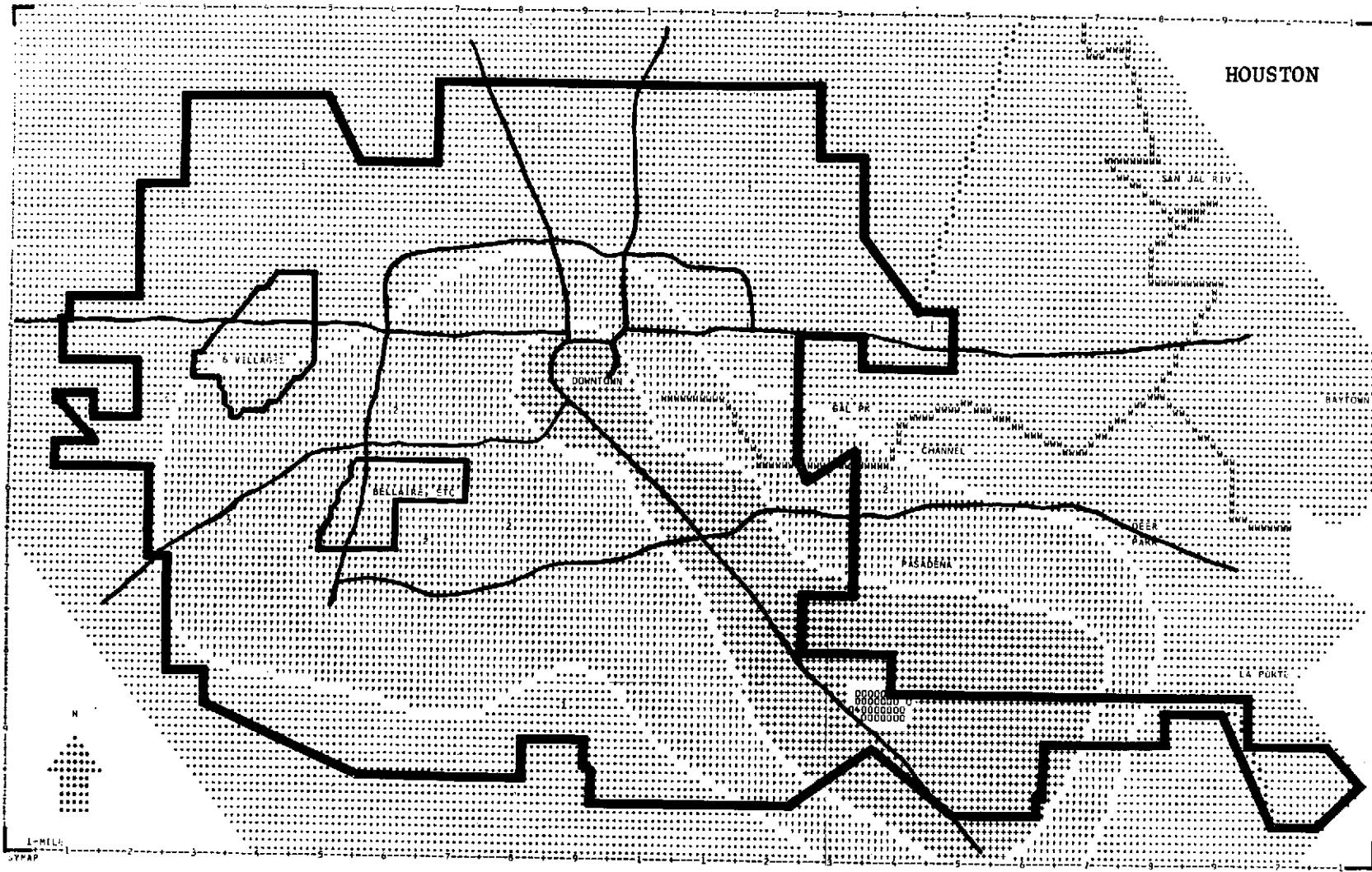


Figure 35. Suspended Particulate Size Distribution  
 0.3 - 10.0  $\mu\text{m}$ , November 29, 1972  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 $(3,700,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	8,000	13,000	18,000	23,000	28,000
Minimum	3,000	8,000	13,000	18,000	23,000
Symbol	.....	.....	+++	0000000	xxxxxx
Frequency	15	5	2	1	0

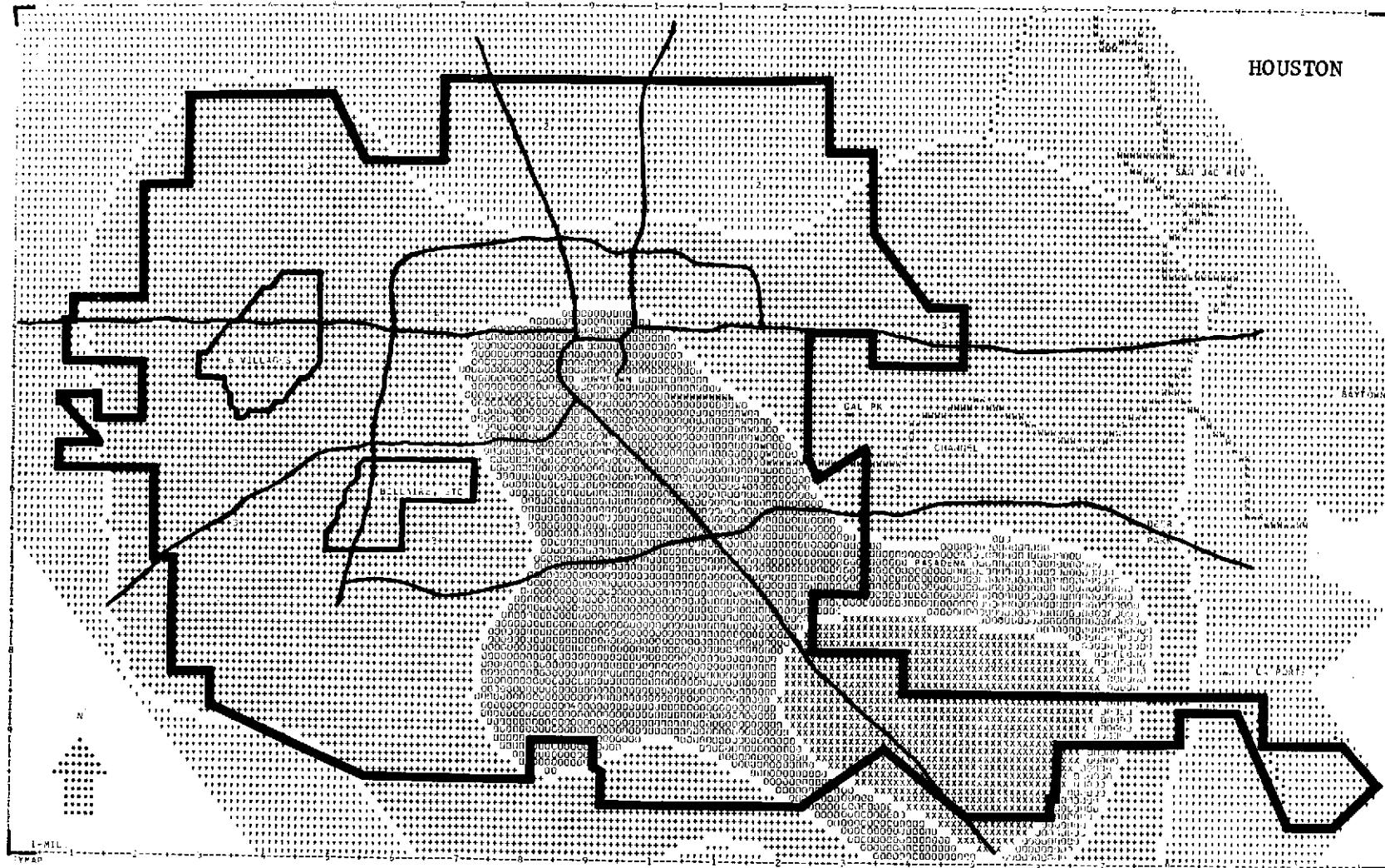


Figure 36. Suspended Particulate Size Distribution  
 0.3 - 10.0  $\mu\text{m}$ , 3-Day Average,  
 November 29, December 1, and 4, 1972  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 $(11,000,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	8,000	13,000	18,000	23,000	28,000
Minimum	3,000	8,000	13,000	18,000	23,000
Symbol	.....	.....	+++	0000000	xxxxxx
Frequency	0	11	8	3	1

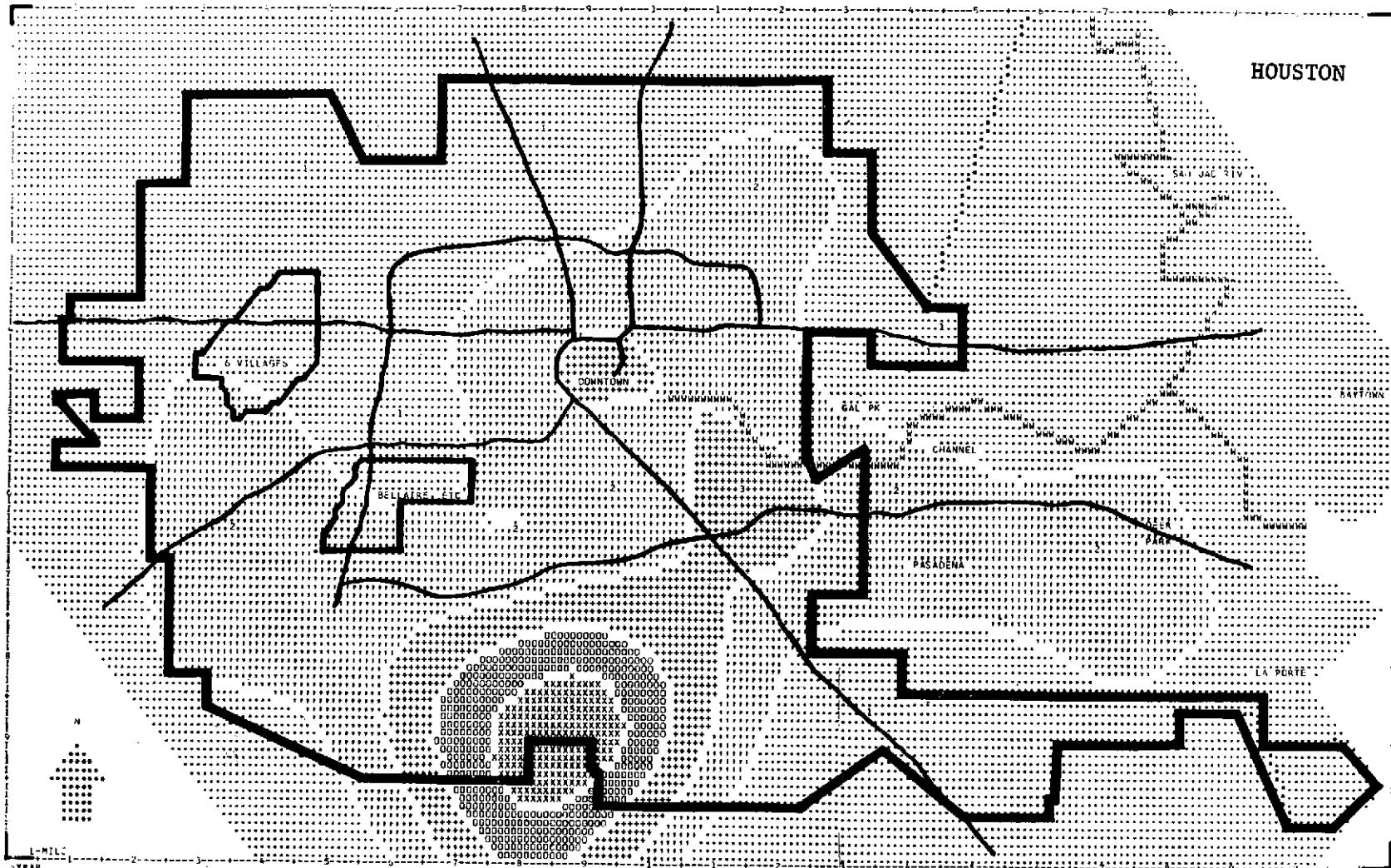


Figure 37. Suspended Particulate Matter  
24-HR Average, November 29, 1972  
Unit:  $\mu\text{g}/\text{m}^3$   
( $30 \mu\text{g}/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	55	85	115	145	175
Minimum	25	55	85	115	145
Symbol	.....	, , ,	+++	00000	xxxxxx
Frequency	15	6	2	0	1

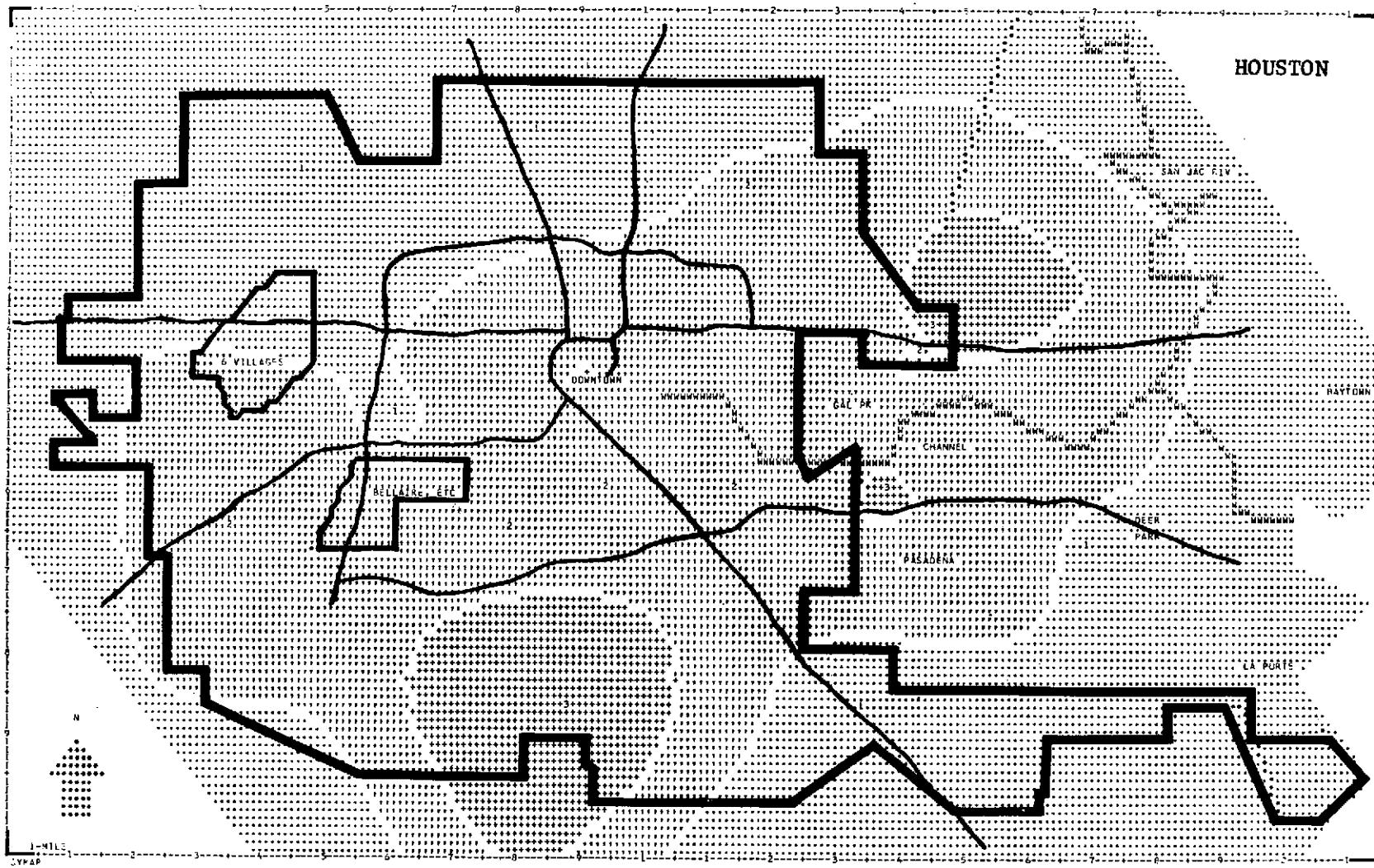


Figure 38. Suspended Particulate Matter  
2-Day, 24-HR Average,  
November 29, and December 5, 1972  
Unit:  $\mu\text{g}/\text{m}^3$   
( $40 \mu\text{g}/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	55	85	115	145	175
Minimum	25	55	85	115	145
Symbol	....	****	+++	00000	xxxxx
Frequency	14	7	3	0	0

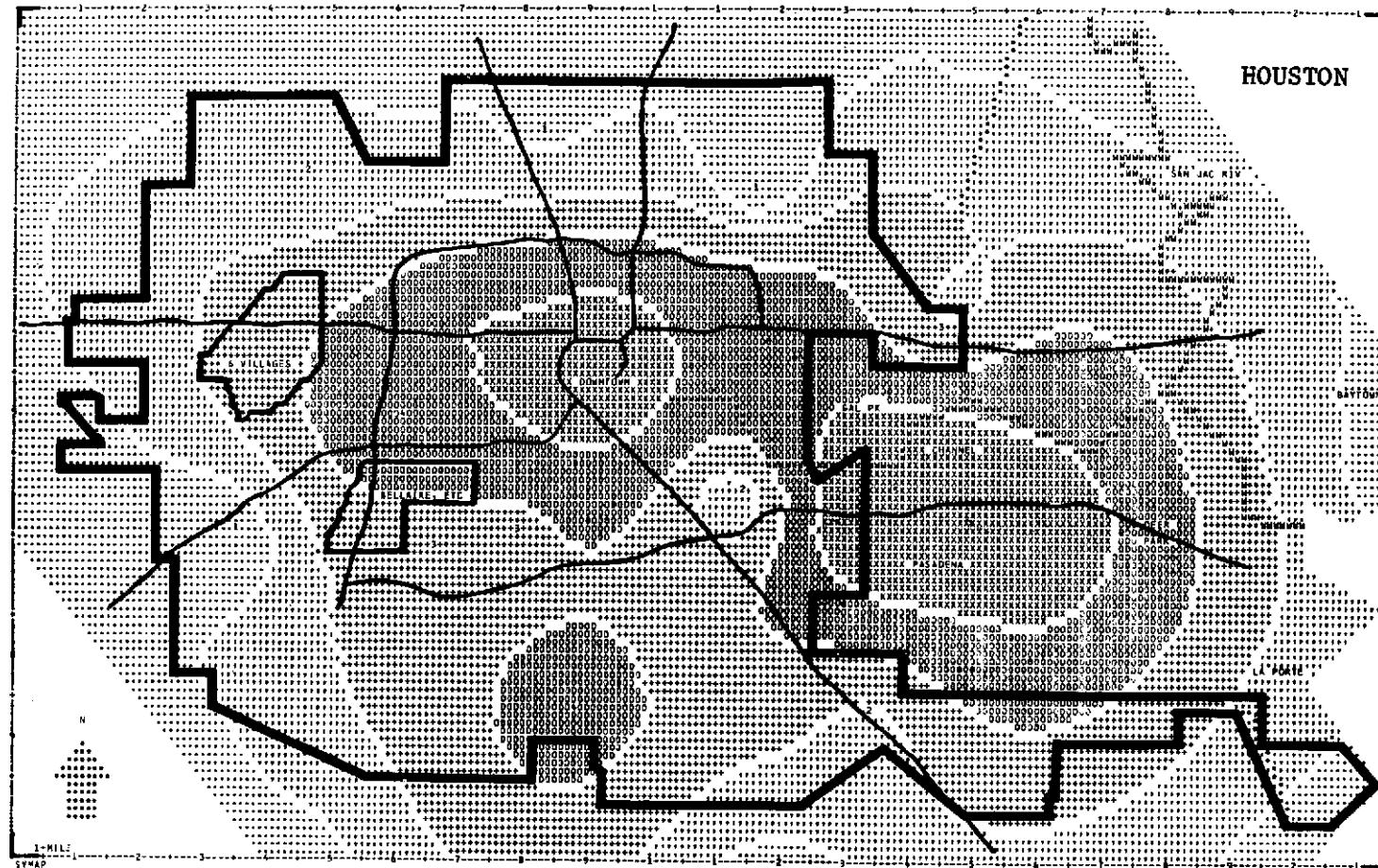


Figure 39. Suspended Particulate Size Distribution  
 0.3 - 0.7  $\mu\text{m}$ , February 15, 1973  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 $(3,450,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	3,561	3,884	4,529	5,819	8,400
Minimum	3,400	3,561	3,884	4,529	5,819
Symbol	.....	.....	+++	000000	xxxxx
Frequency	12	3	3	3	2

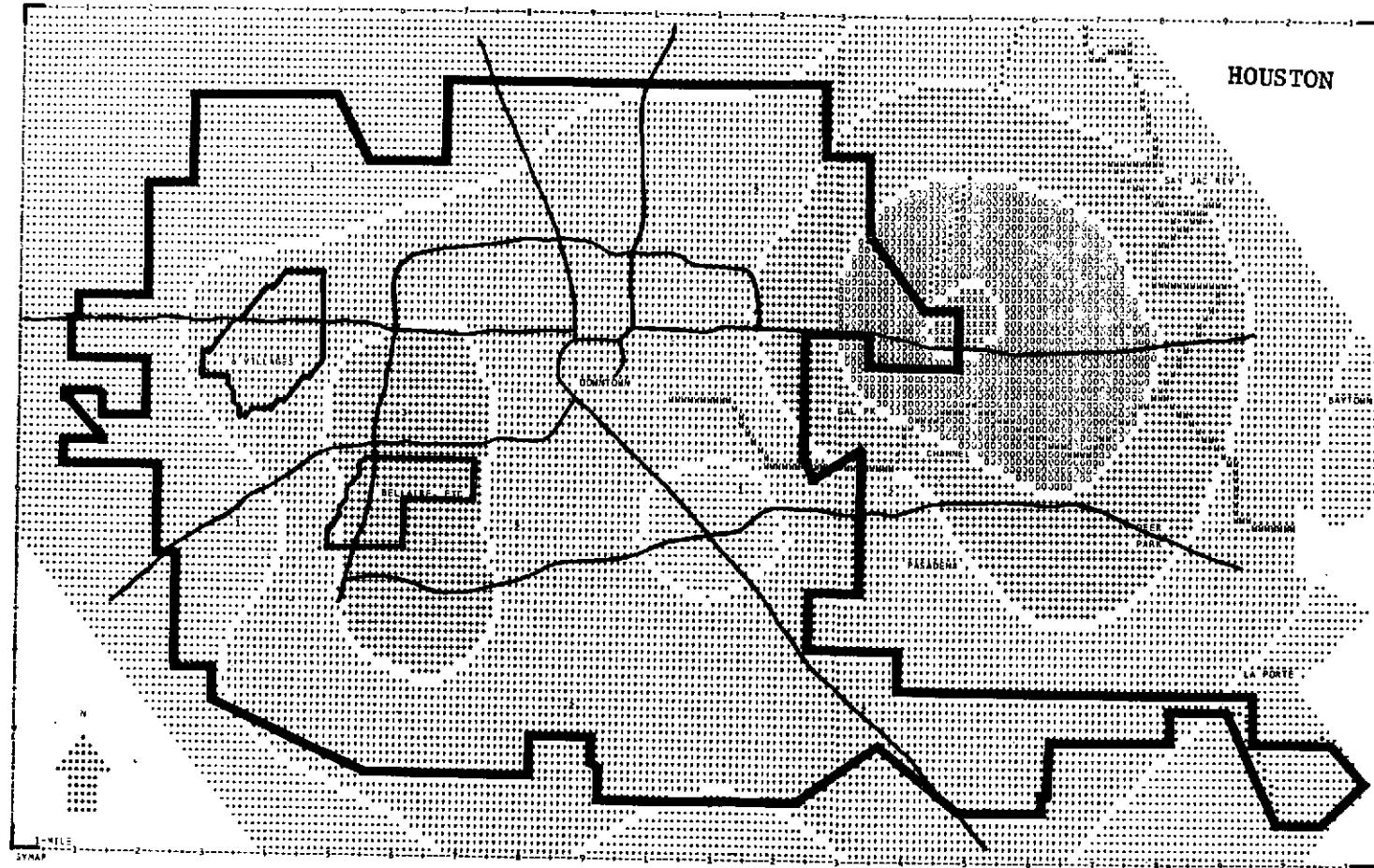


Figure 40. Suspended Particulate Size Distribution  
 $0.3 - 0.7 \mu\text{m}$ , 3-Day Average  
 February 5, 6, and 15, 1973  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 $(3,400,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	4,548	7,645	13,839	26,226	51,000
Minimum	3,000	4,548	7,645	13,839	26,226
Symbol	.....		+ + +	0000000	xxxxxx
Frequency	13	7	2	0	1

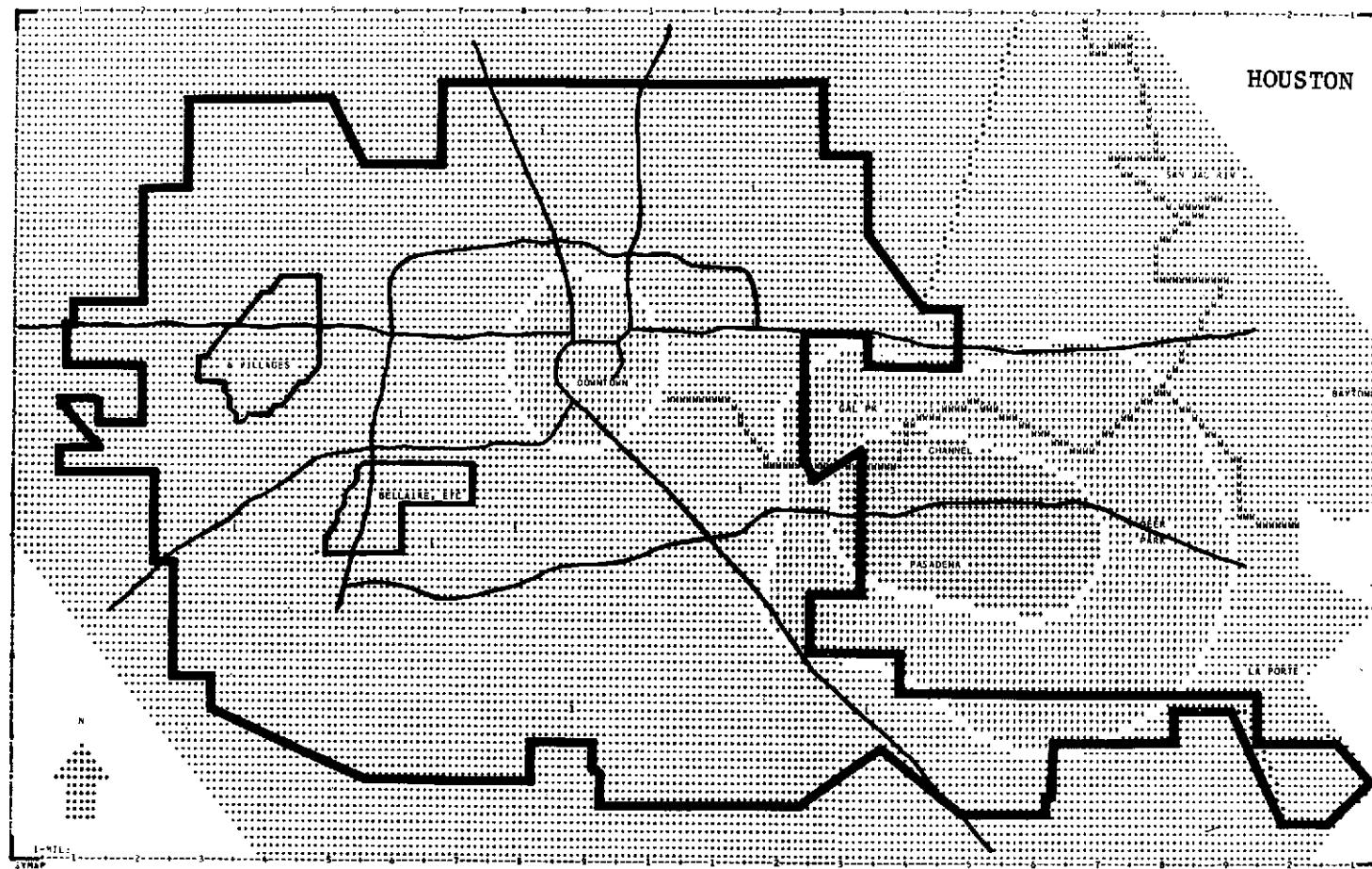


Figure 41. Suspended Particulate Size Distribution  
 0.7 - 1.4  $\mu\text{m}$ , February 15, 1973  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 $(210,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	400	800	1,600	3,200	6,400
Minimum	200	400	800	1,600	3,200
Symbol	.....	,....,	+++	000000	xxxxxx
Frequency	21	1	1	0	0

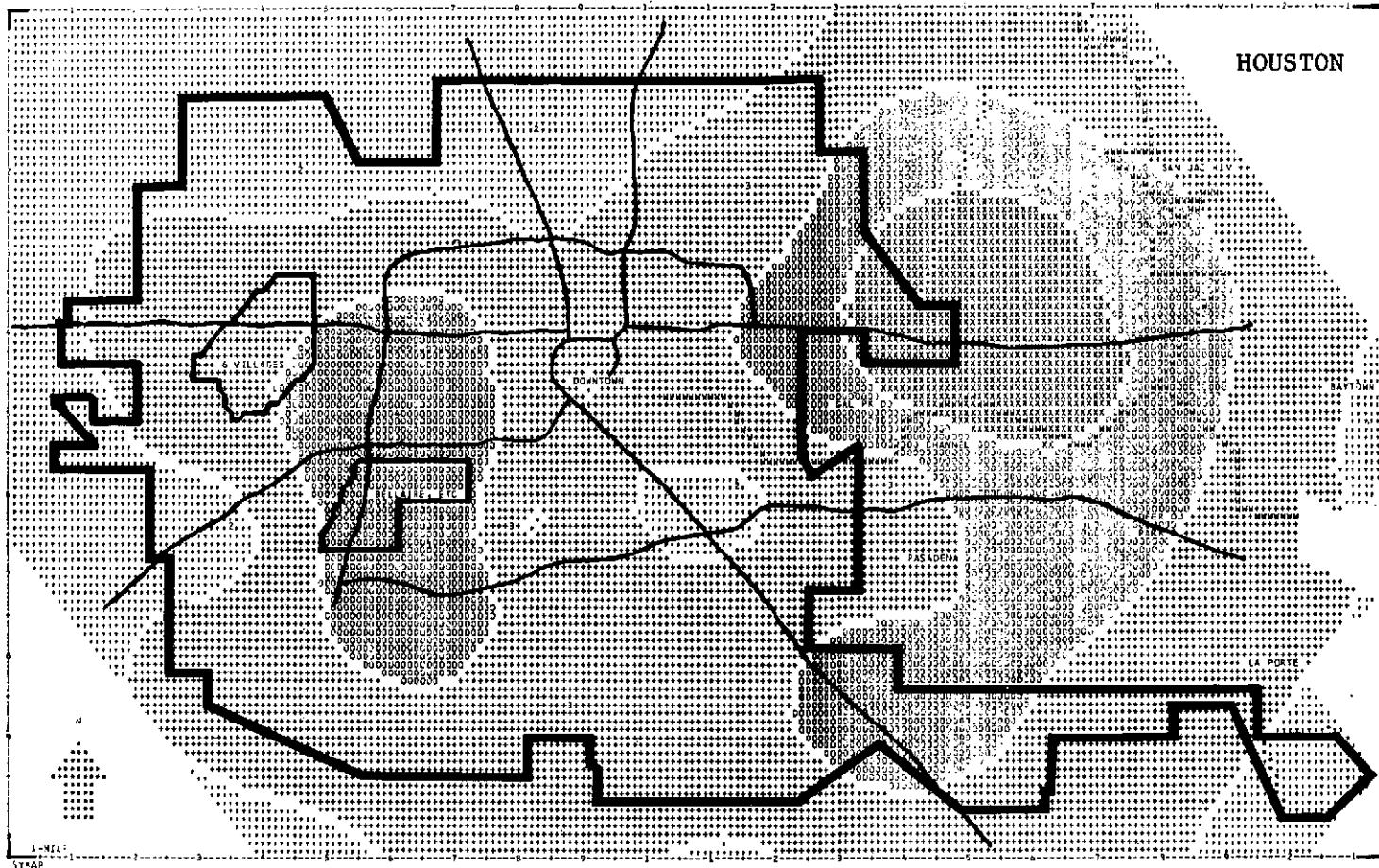


Figure 42. Suspended Particulate Size Distribution  
 0.7 - 1.4  $\mu\text{m}$ , 3-Day Average  
 February 5, 6, and 15, 1973  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 $(650,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	400	800	1,600	3,200	6,400
Minimum	200	400	800	1,600	3,200
Symbol	....		+ + +	000000	xxxxxx
Frequency	0	13	5	4	1

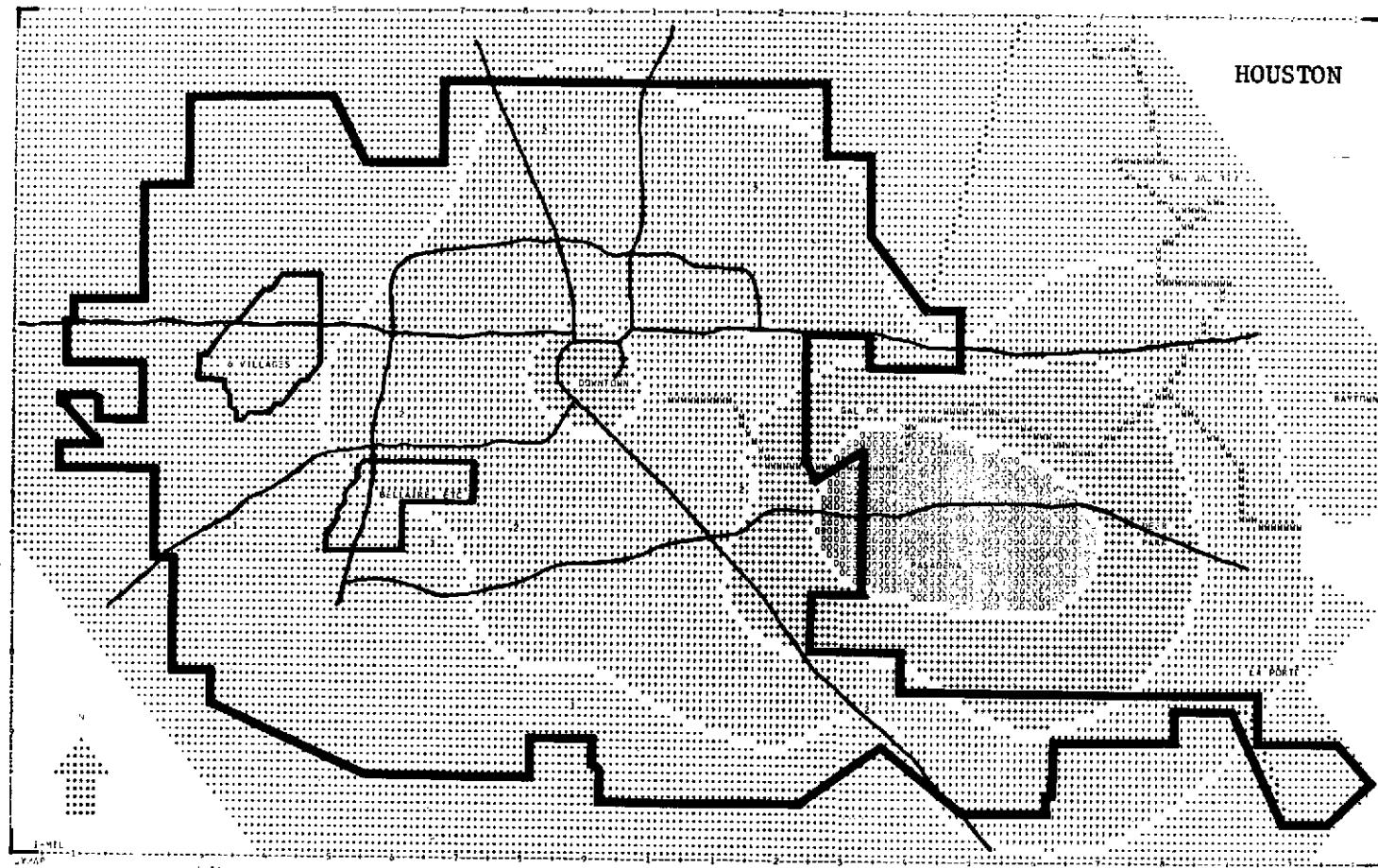


Figure 43. Suspended Particulate Size Distribution  
 1.4 - 3.0  $\mu\text{m}$ , February 15, 1973  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 $(60,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	100	200	400	800	1,600
Minimum	50	100	200	400	800
Symbol	.....	,.....	+ + +	00000	xxxxxx
Frequency	15	6	1	1	0

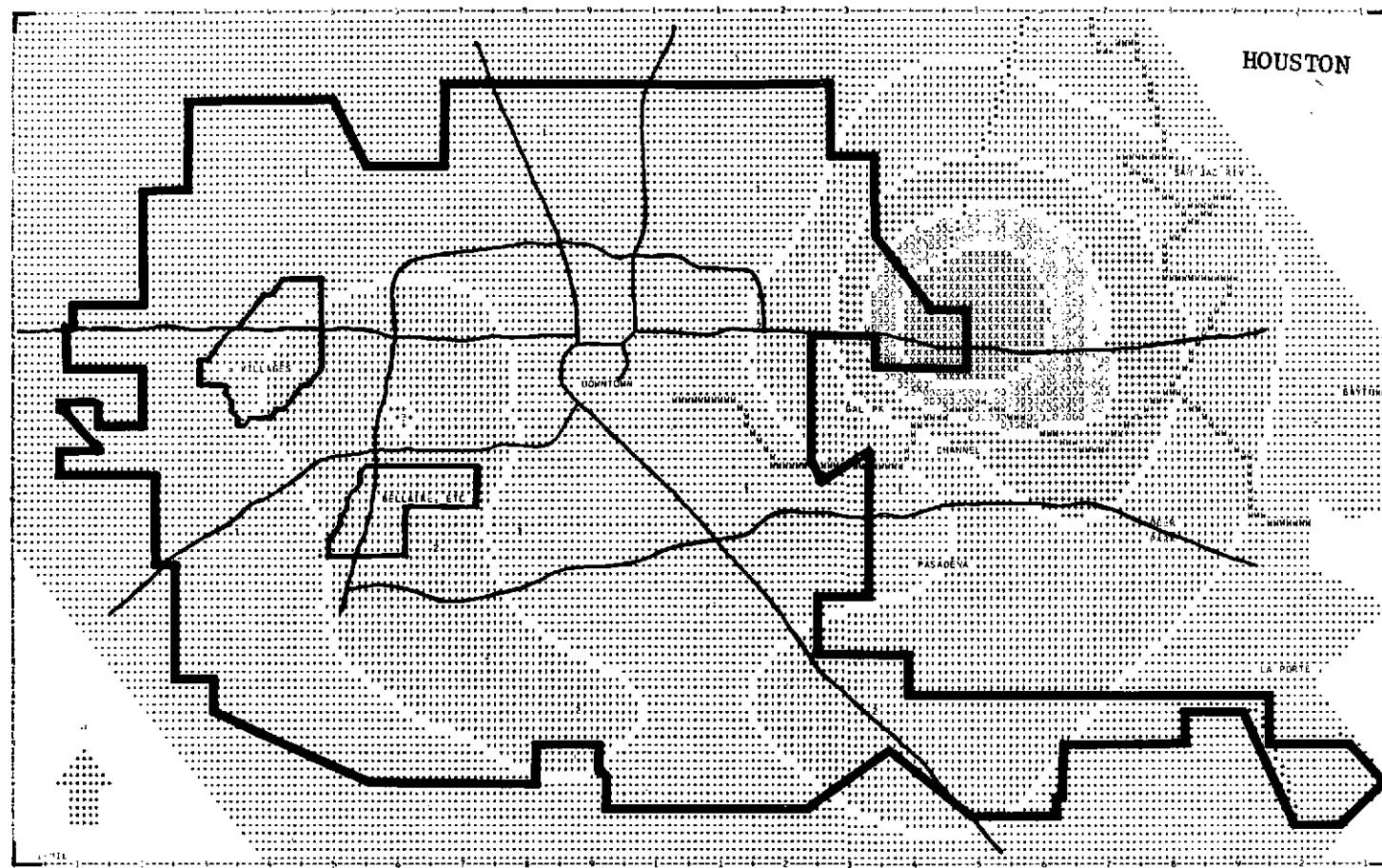


Figure 44. Suspended Particulate Size Distribution  
 1.4 - 3.0  $\mu\text{m}$ , 3-Day Average  
 February 5, 6, and 15, 1973  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 $(425,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	854	1,608	2,362	3,116	3,870
Minimum	100	854	1,608	2,362	3,116
Symbol	.....	,,.,,	+++	0000000	xxxxxx
Frequency	17	4	1	0	1

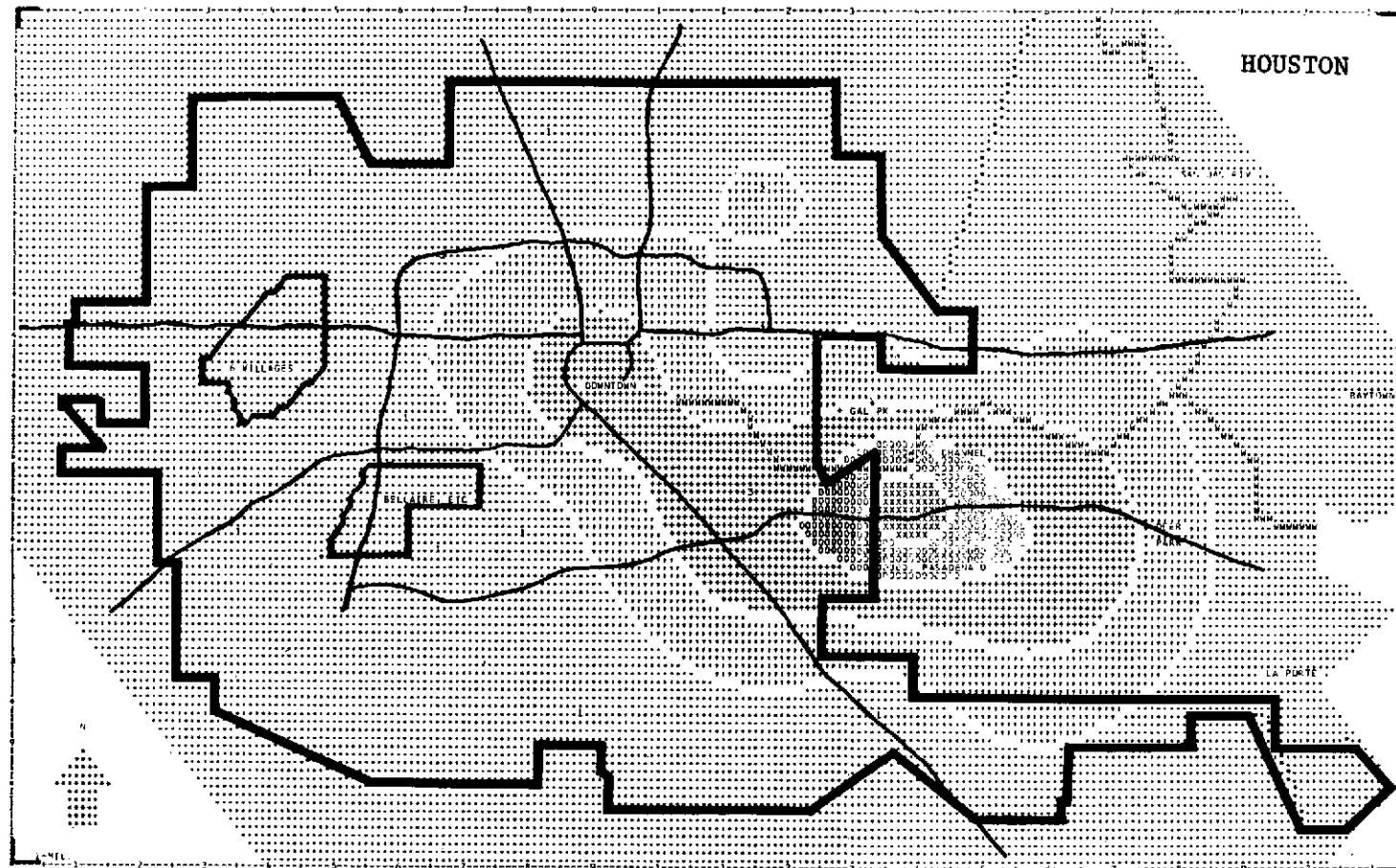


Figure 45. Suspended Particulate Size Distribution  
 $3.0 - 10.0 \mu\text{m}$ , February 315, 1973  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 $(7,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	17	27	37	47	57
Minimum	7	17	27	37	47
Symbol	....	,,	+++	00000	xxxxx
Frequency	19	1	2	0	1

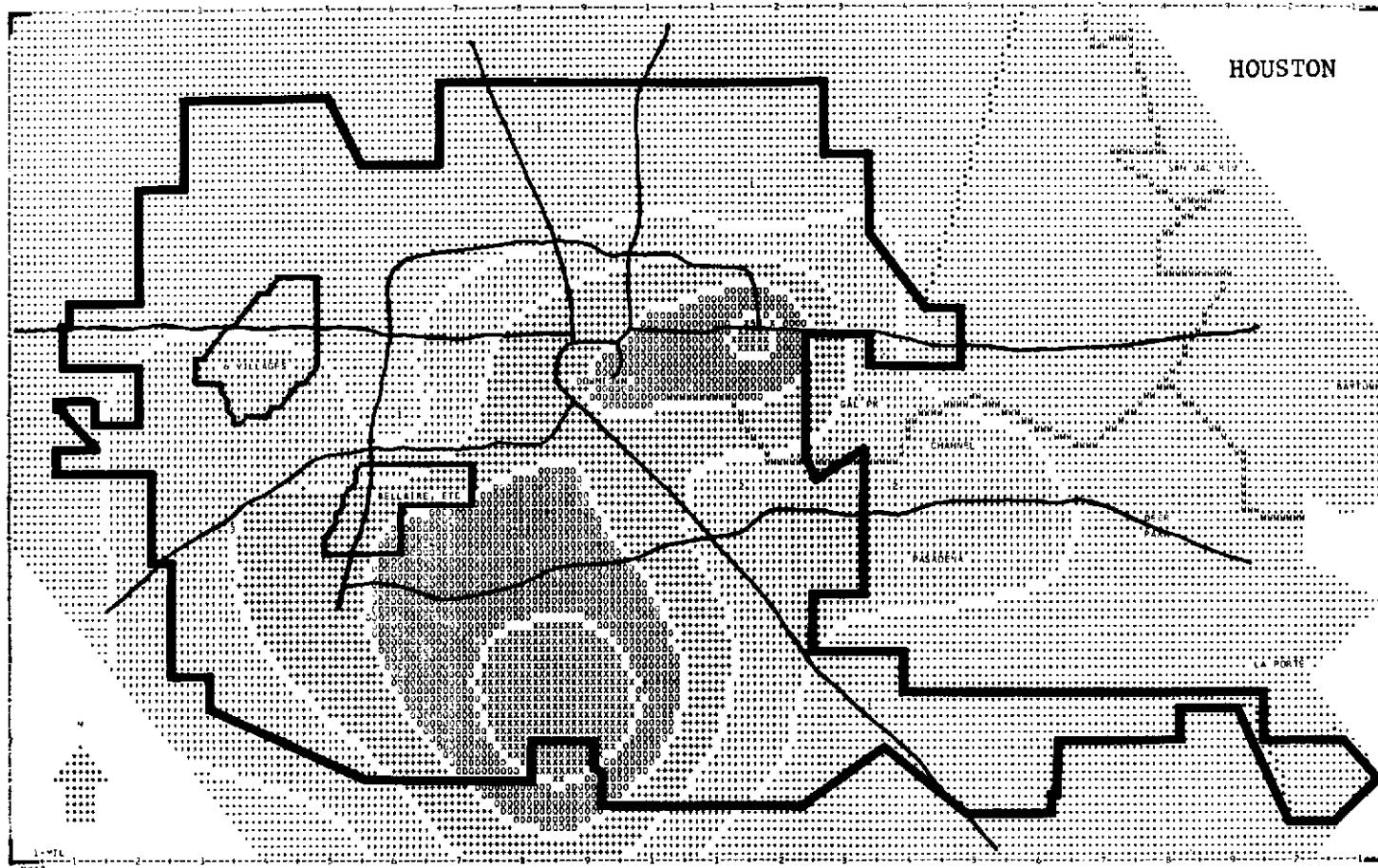


Figure 46. Suspended Particulate Size Distribution  
 3.0 - 10.0  $\mu\text{m}$ , 3-Day Average  
 February 5, 6, and 15, 1973  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 $(72,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	75	80	85	90	95
Minimum	70	75	80	85	90
Symbol	....	---	+ + +	00000	xxxxxxx
Frequency	15	2	1	3	2

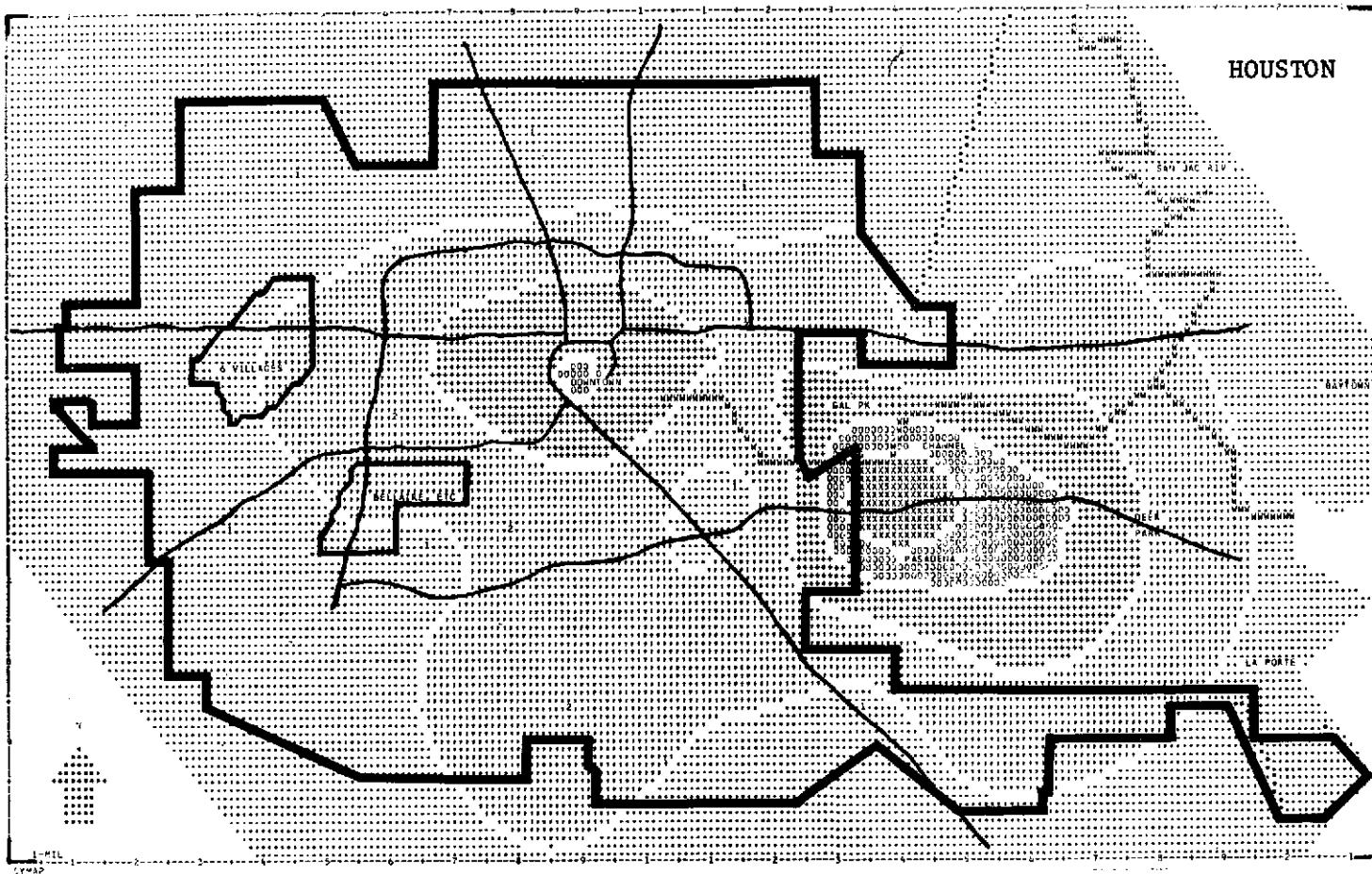


Figure 47. Suspended Particulate Size Distribution  
 $0.3 - 10.0 \mu\text{m}$ , February 15, 1973  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 $(3,800,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	4,500	6,000	7,500	9,000	10,500
Minimum	3,000	4,500	6,000	7,500	9,000
Symbol	.....	,, , ,	++ +	000000	xxxxxx
Frequency	17	5	0	1	1

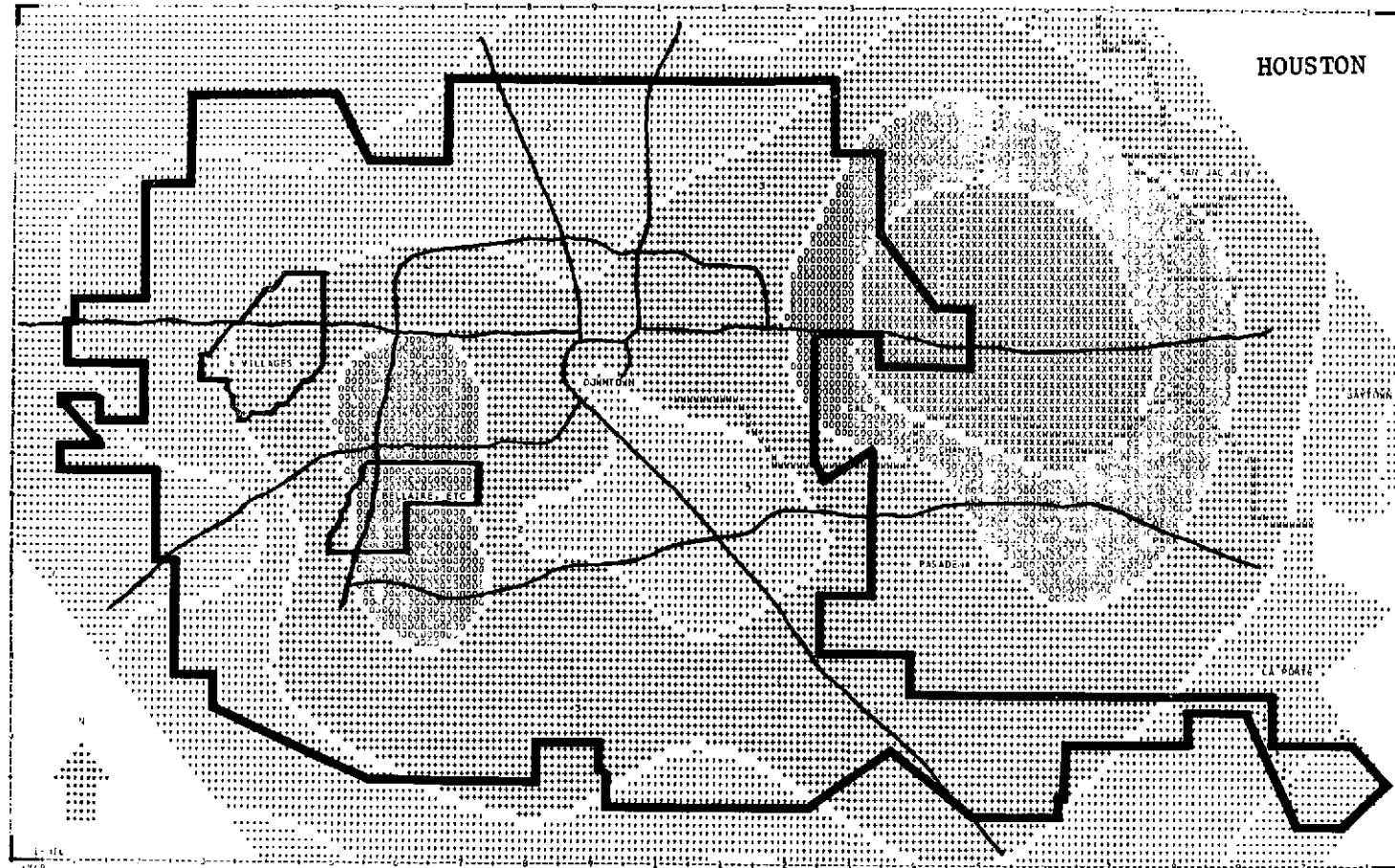


Figure 48. Suspended Particulate Size Distribution  
 0.3 - 10.0  $\mu\text{m}$ , 3-Day Average,  
 February 5, 6, and 15, 1973  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 $(4,500,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	5,032	7,097	11,226	19,484	36,000
Minimum	4,000	5,032	7,097	11,226	19,484
Symbol	.....	,, , ,	++ +	0000000	xxxxxx
Frequency	11	4	5	2	1

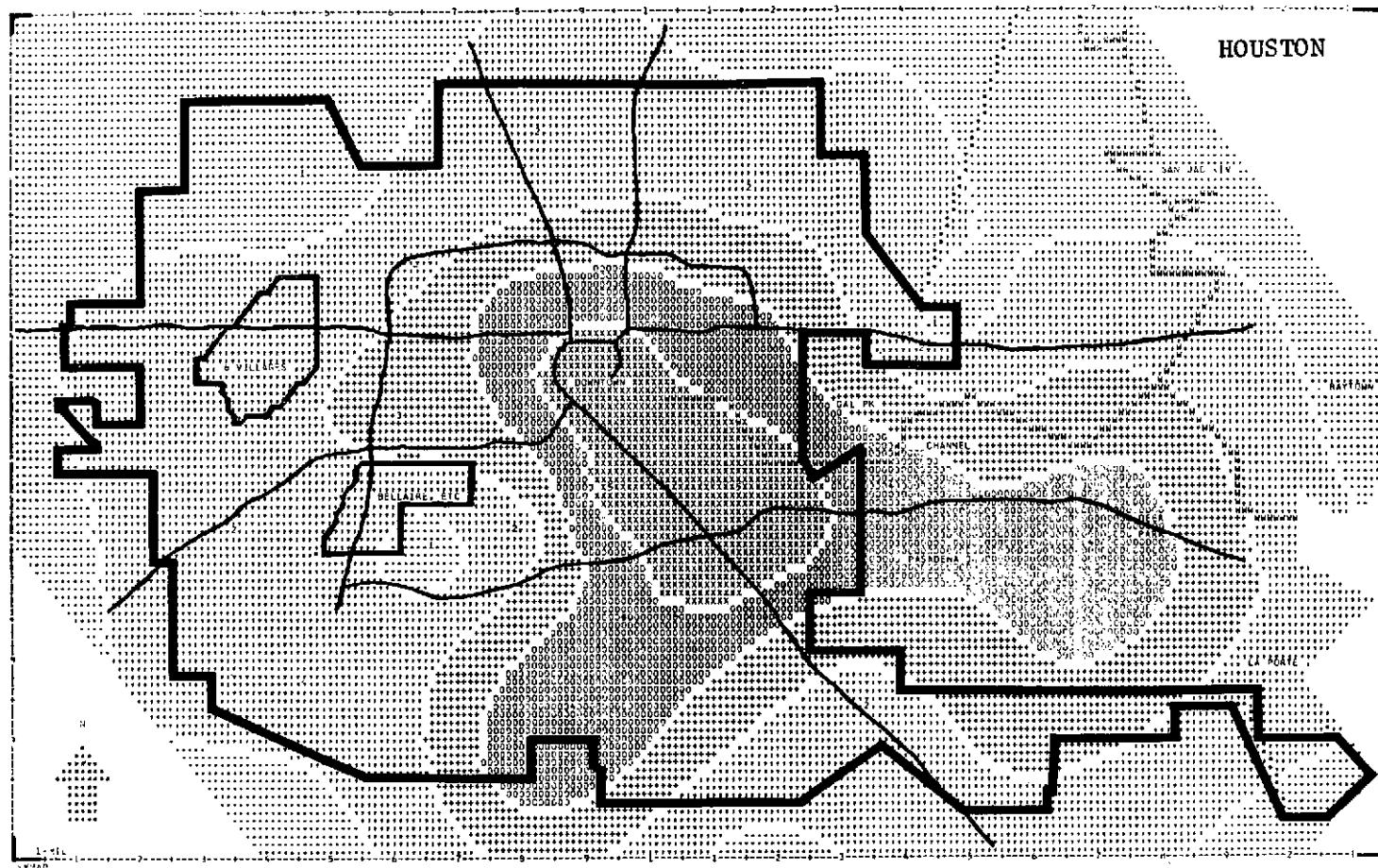


Figure 49. Suspended Particulate Matter  
24-HR Average, February 15, 1973  
Unit:  $\mu\text{g}/\text{m}^3$   
( $43 \mu\text{g}/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	50	70	90	110	130
Minimum	30	50	70	90	110
Symbol	....	,,	++	00000	xxxx
Frequency	12	6	1	4	3

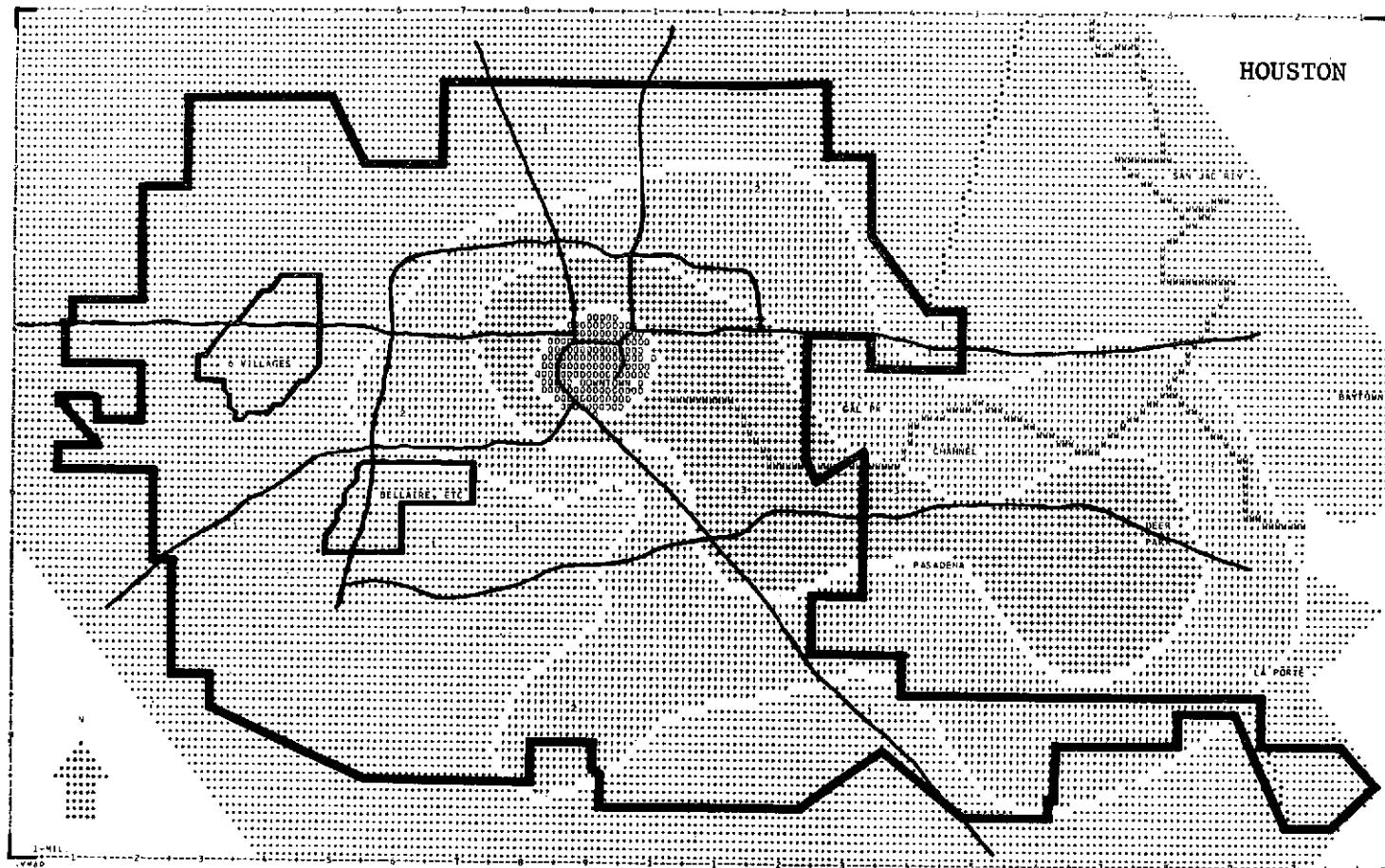


Figure 50. Suspended Particulate Matter  
2-Day, 24-HR Average  
February 9 and 15, 1973  
Unit:  $\mu\text{g}/\text{m}^3$   
( $33 \mu\text{g}/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	50	70	90	110	130
Minimum	30	50	70	90	110
Symbol	....	,,	++	0000	xxxxx
Frequency	12	6	1	4	3

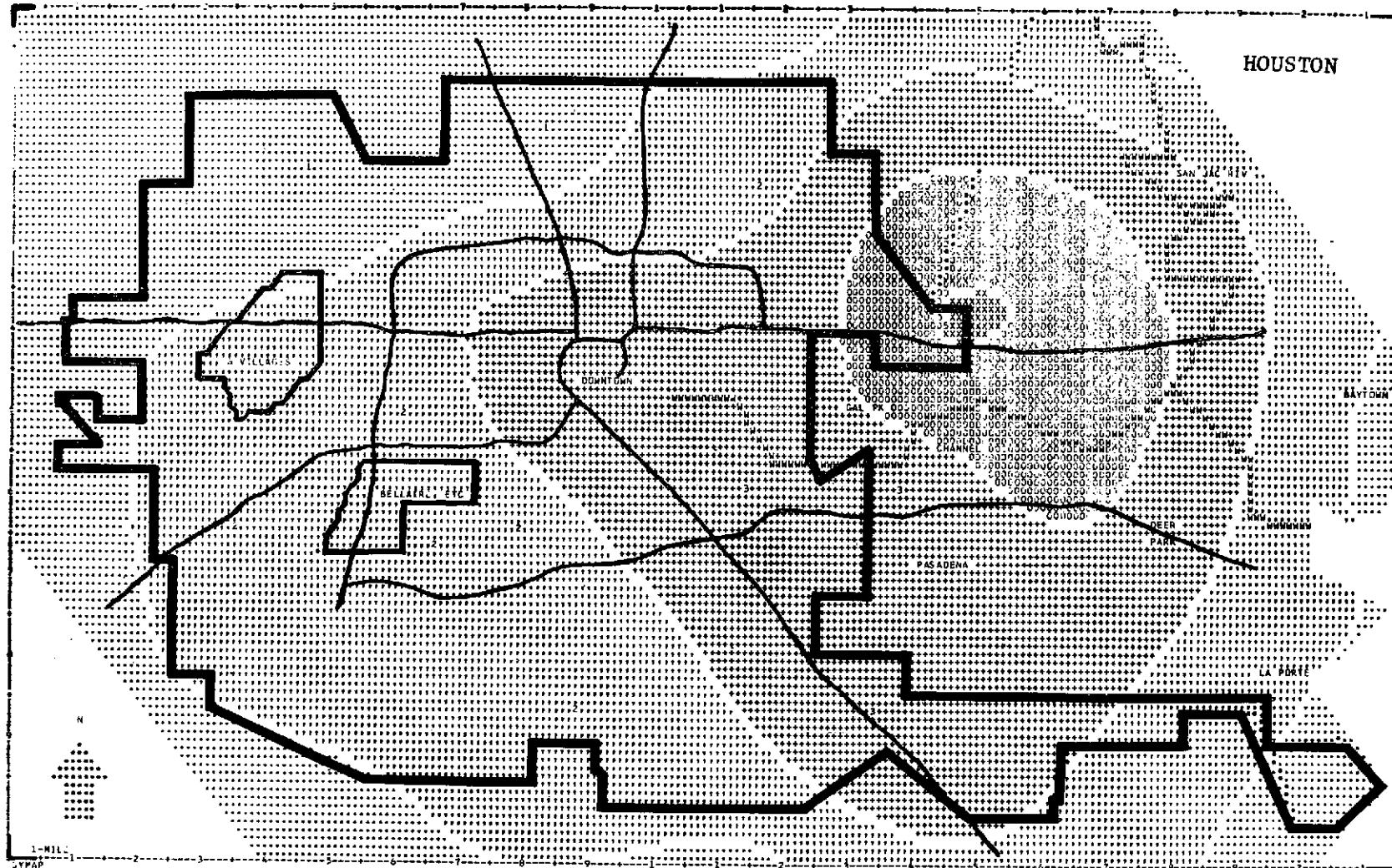


Figure 51. Suspended Particulate Size Distribution  
 0.3 - 0.7  $\mu\text{m}$ , 3-Day Average  
 8-25, 11-29, 1972 and 2-15, 1973  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 $(3,400,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	4,032	6,097	10,226	18,484	35,000
Minimum	3,000	4,032	6,097	10,226	18,484
Symbol	.....	,,.,,	+++	000000	xxxxxx
Frequency	11	6	5	0	1

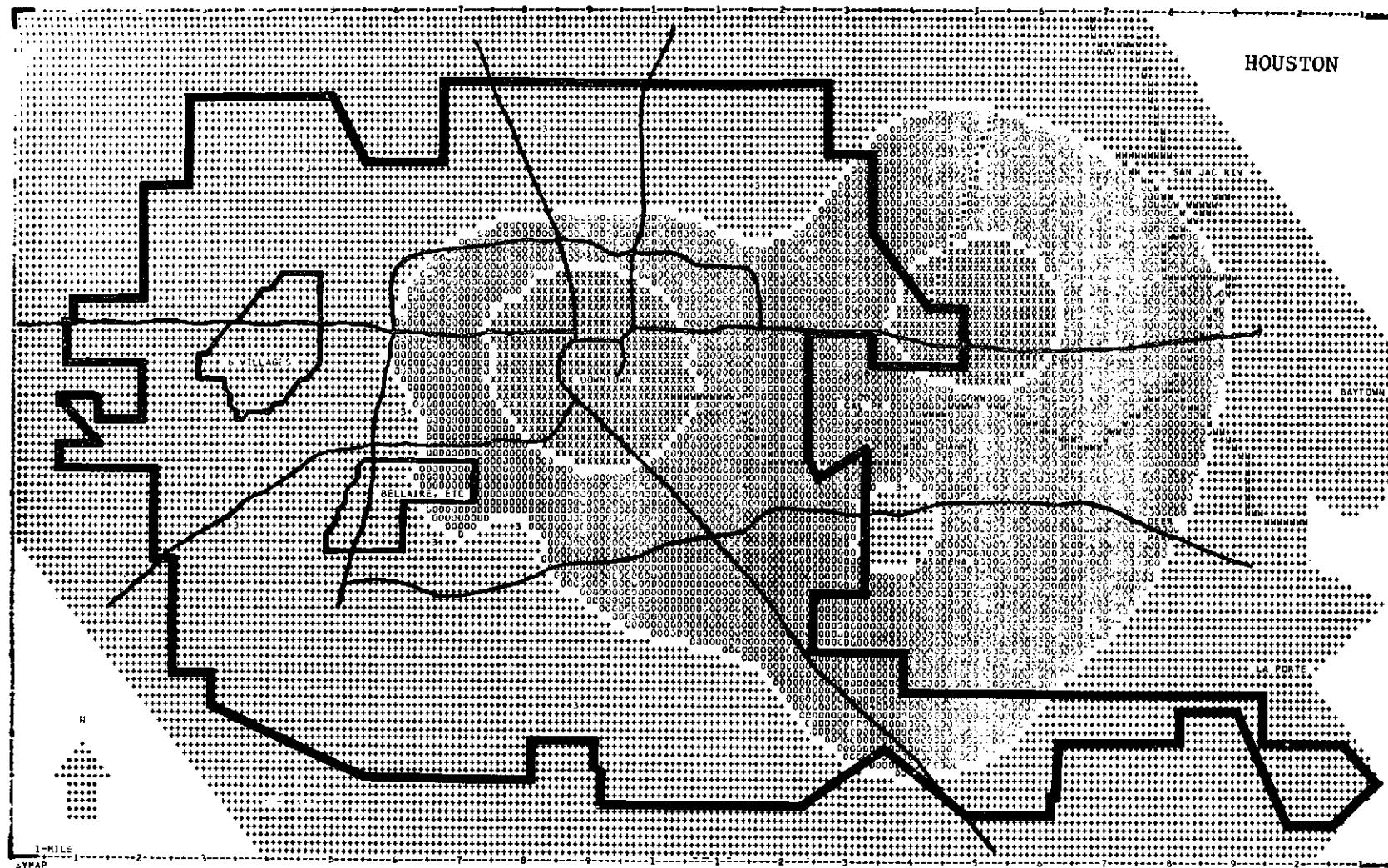


Figure 52. Suspended Particulate Size Distribution  
 0.3 - 0.7  $\mu\text{m}$ , 9-Day Average,  
 8-23, 25, 28, 11-29, 12-1, 4, 1972, and  
 2-5, 6, 15, 1973  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 ( $6,300,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	4,032	6,097	10,226	18,484	35,000
Minimum	3,000	4,032	6,097	10,226	18,484
Symbol	.....	, , , ,	++ + +	000000	xxxxxx
Frequency	0	0	18	3	2

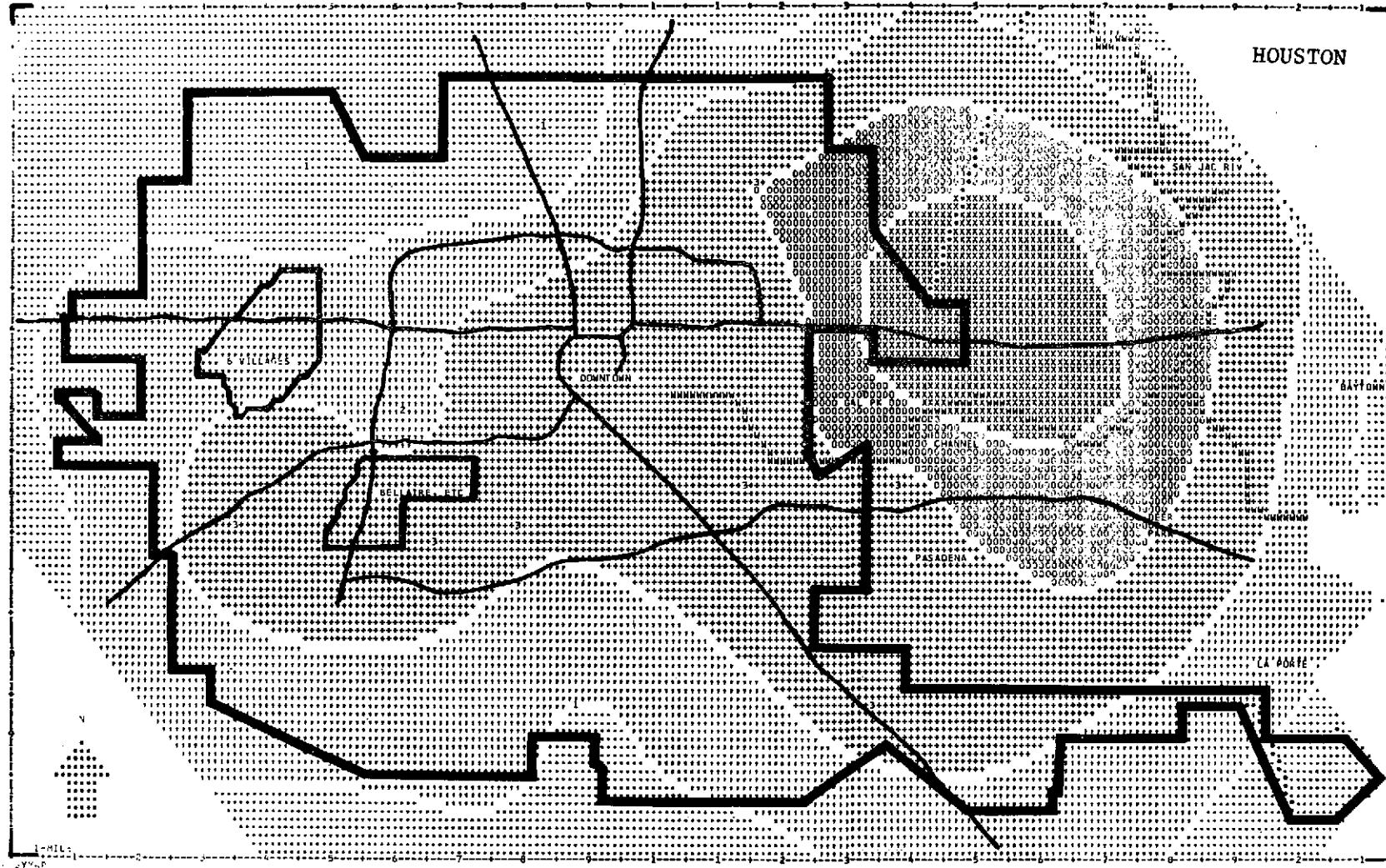


Figure 53. Suspended Particulate Size Distribution  
 0.7 - 1.4  $\mu\text{m}$ , 3-Day Average  
 8-25, 11-29, 1972 and 2-15, 1973  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 (630,000/ $\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	703	910	1,323	2,148	3,800
Minimum	600	703	910	1,323	2,148
Symbol	....	,,	++	000000	xxxxxx
Frequency	12	1	9	0	1

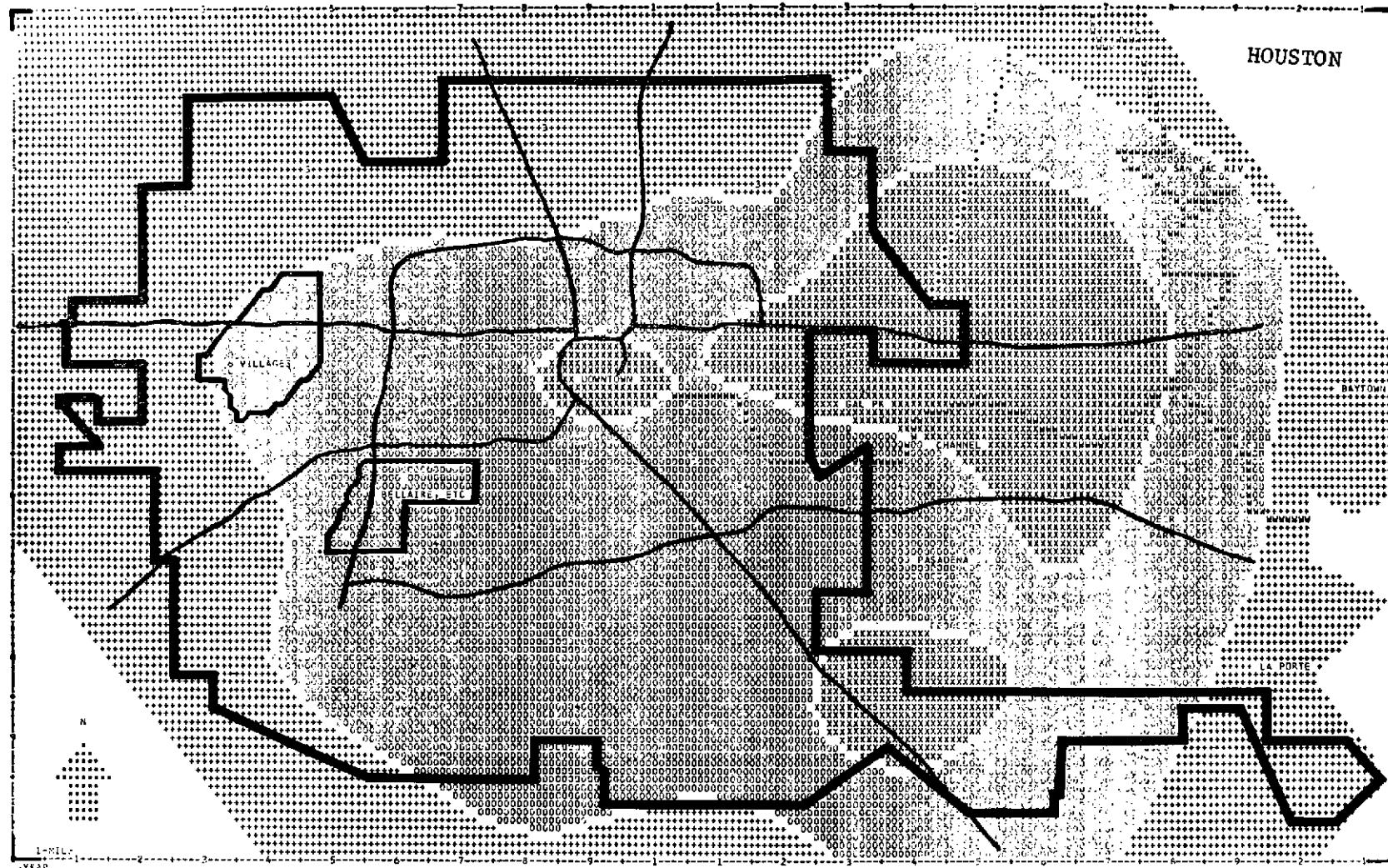


Figure 54. Suspended Particulate Size Distribution  
 0.7 - 1.4  $\mu\text{m}$ , 9-Day Average,  
 8-23, 25, 28, 11-29, 12-1, 4, 1972 and  
 2-5, 6, 15, 1973  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 $(950,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	703	910	1,323	2,148	3,800
Minimum	600	703	910	1,323	2,148
Symbol	.....	.....	+++	00000	XXXXXX
Frequency	0	0	13	6	4

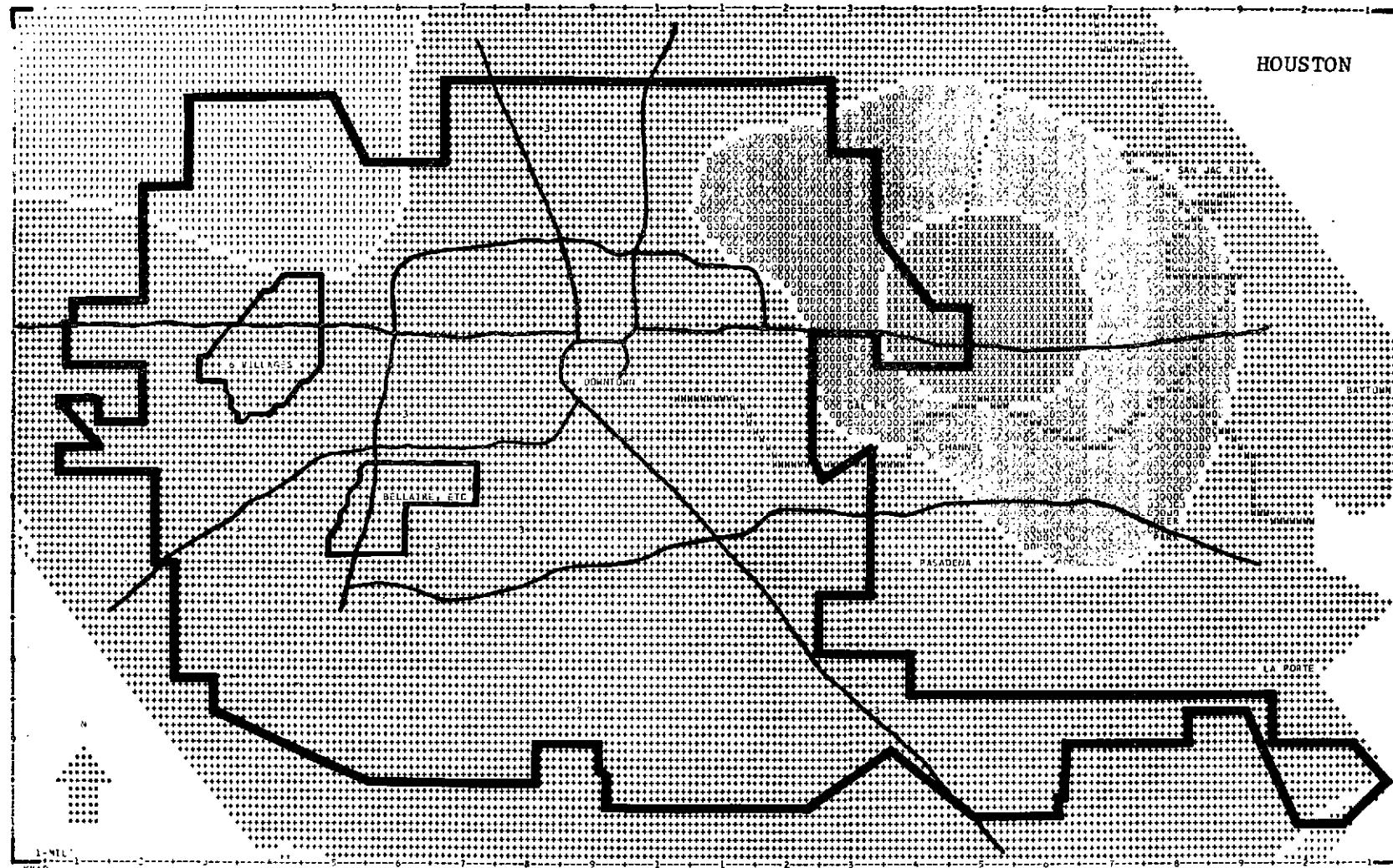


Figure 55. Suspended Particulate Size Distribution  
 1.4 - 3.0  $\mu\text{m}$ , 3-Day Average,  
 8-25, 11-29, 1972, and 2-15, 1973  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 (600,000/ $\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	403	610	1,023	1,848	3,500
Minimum	300	403	610	1,023	1,848
Symbol	.....	, , , ,	+ + +	000000	x x x x x
Frequency	0	10	11	1	1

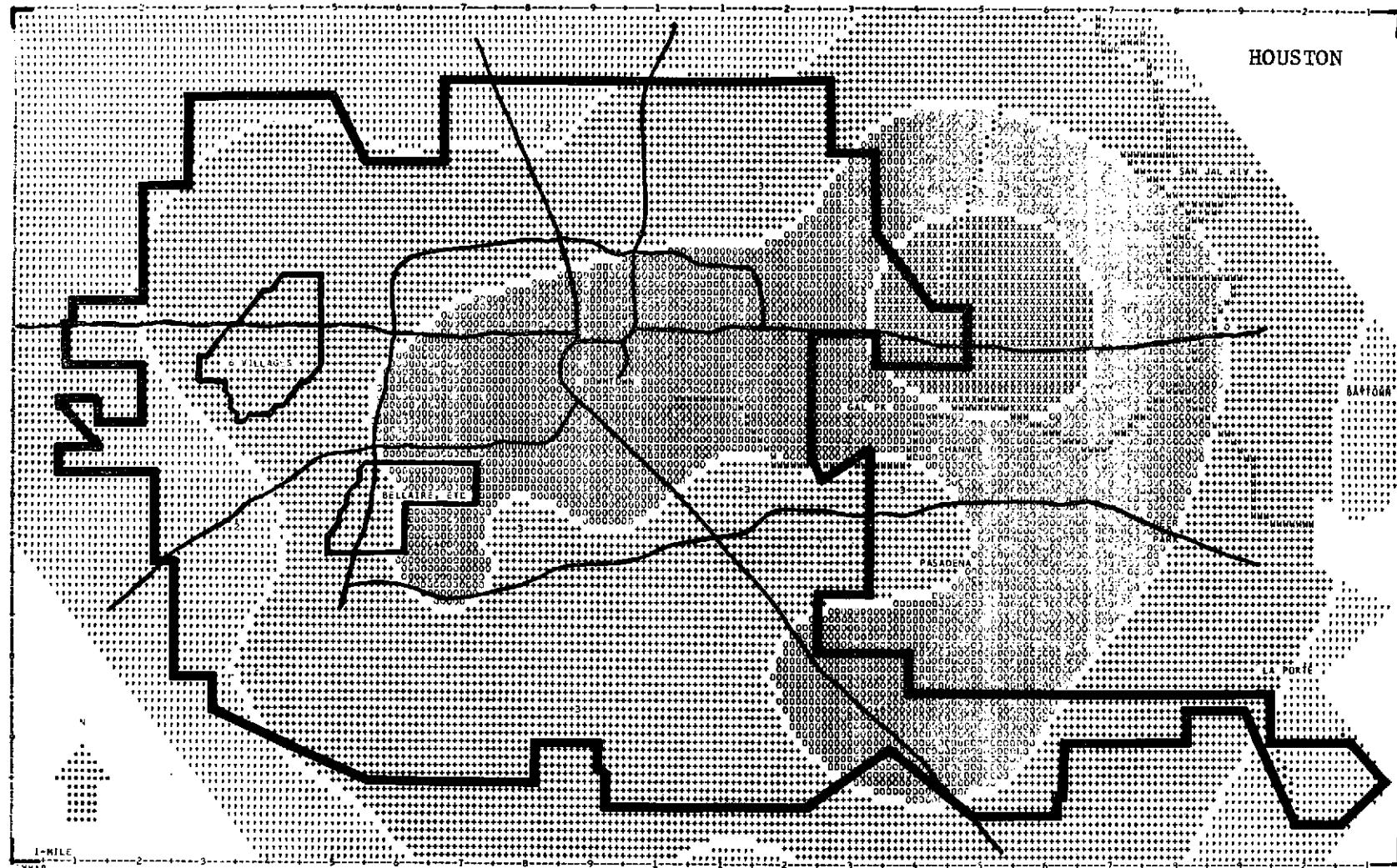


Figure 56. Suspended Particulate Size Distribution  
 1.4 - 3.0  $\mu\text{m}$ , 9-Day Average,  
 8-23, 25, 28, 11-29, 12-1, 4, 1972  
 and 2-5, 6, 15, 1973  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 $(500,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	403	610	1,023	1,848	3,500
Minimum	300	403	610	1,023	1,848
Symbol	....	,, , ,	++ +	000000	xxxxxx
Frequency	0	11	6	5	1

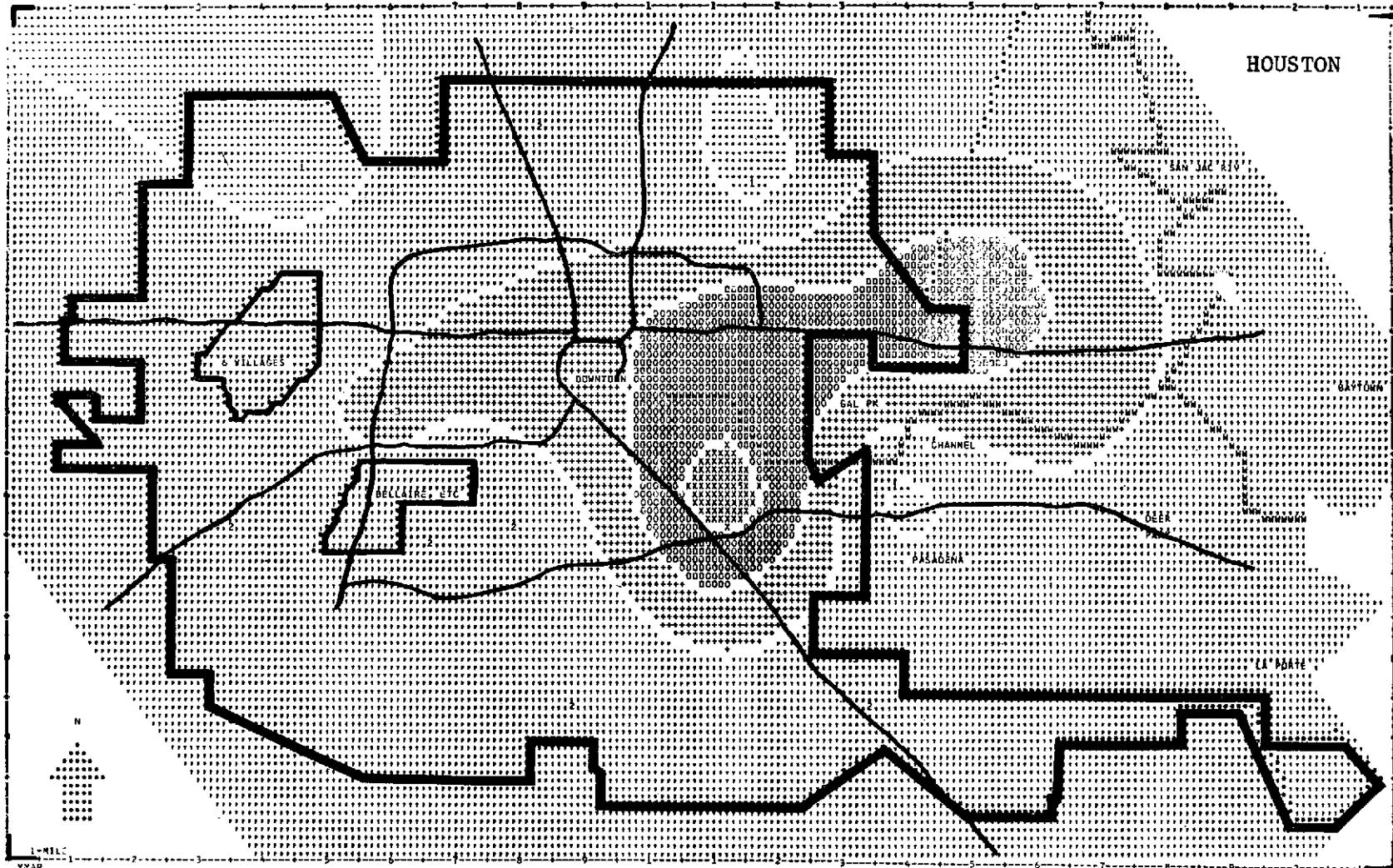


Figure 57. Suspended Particulate Size Distribution  
 3.0 - 10.0  $\mu\text{m}$ , 3-Day Average,  
 8-25, 11-29, 1972, and 2-15, 1973  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 (60,000  $/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	60	70	80	90	100
Minimum	50	60	70	80	90
Symbol	....	,,,	+++	0000	xxxxx
Frequency	3	15	2	2	1

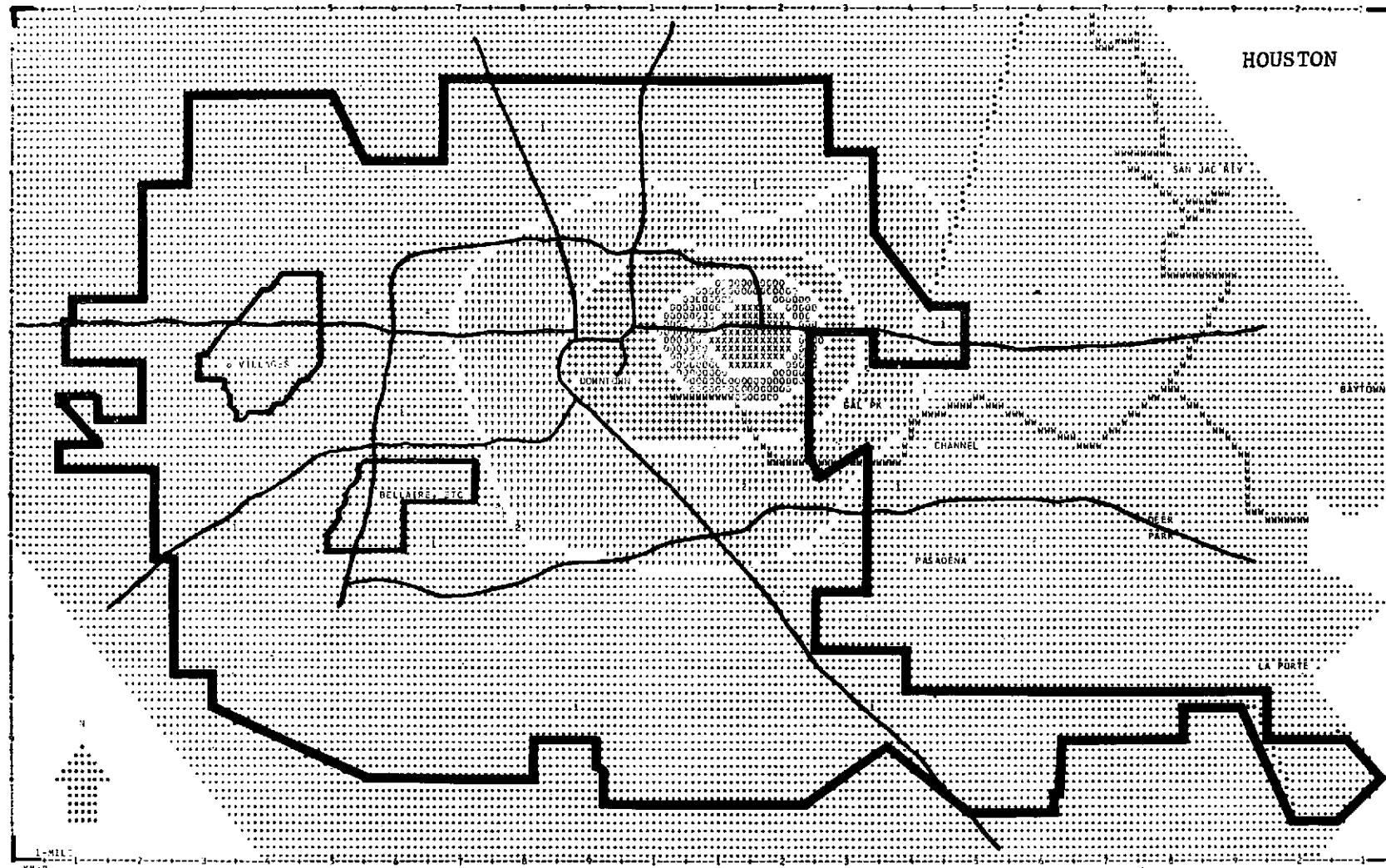


Figure 58. Suspended Particulate Size Distribution  
 3.0 - 10.0  $\mu\text{m}$ , 9-Day Average,  
 8-23, 25, 28, 11-29, 12-1, 4, 1972 and  
 2-5, 6, 15, 1973  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 $(60,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	100	150	200	250	300
Minimum	50	100	150	200	250
Symbol	....	, , ,	+++	00000	xxxxxx
Frequency	19	2	1	0	1

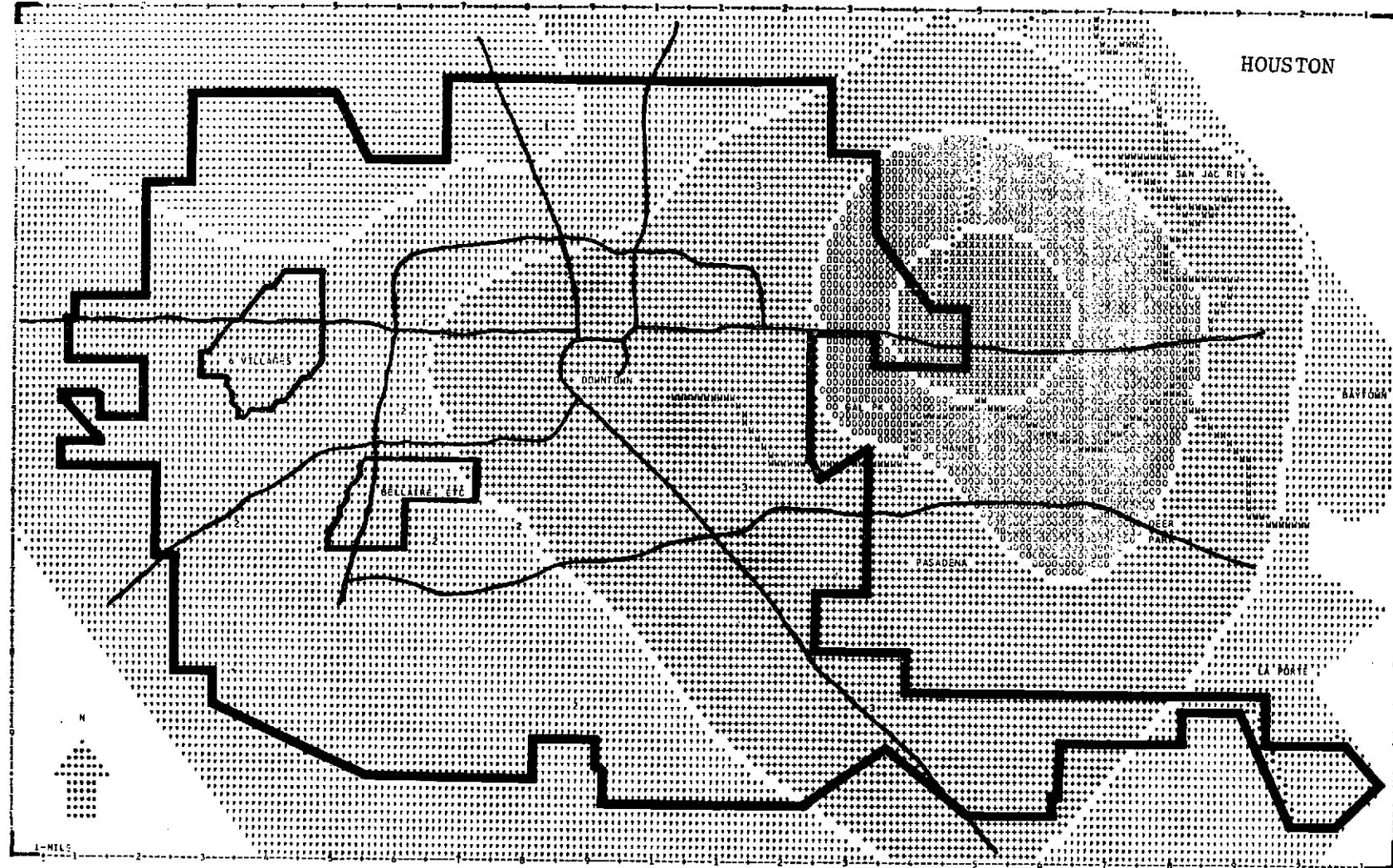


Figure 59. Suspended Particulate Size Distribution  
 0.3 - 10.0  $\mu\text{m}$ , 3-Day Average  
 8-25, 11-29, 1972 and 2-15, 1972  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 $(5,000,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	5,032	7,097	11,226	19,484	36,000
Minimum	4,000	5,032	7,097	11,226	19,484
Symbol	.....	.....	+++	000000	xxxxxx
Frequency	11	5	6	0	1

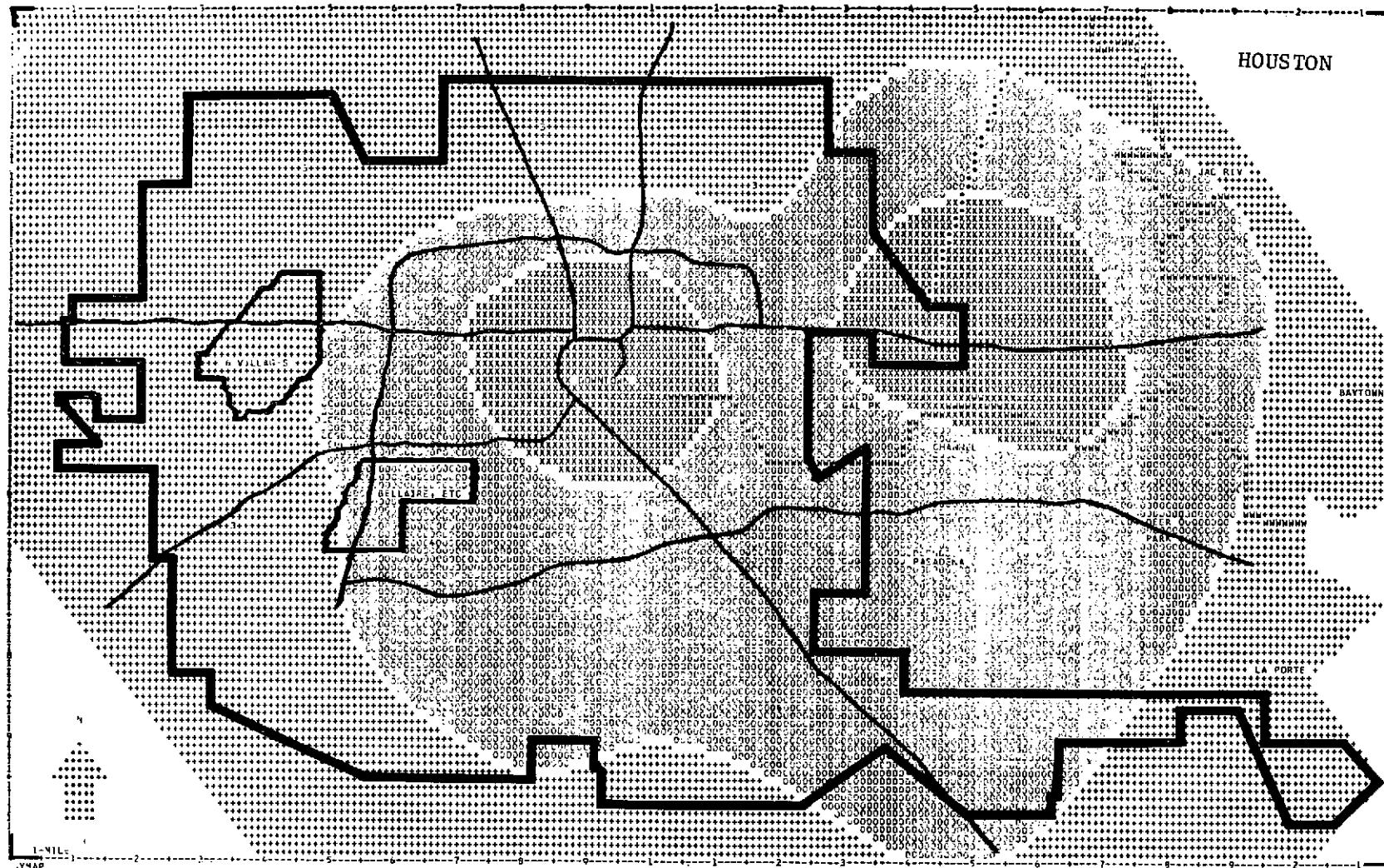


Figure 60. Suspended Particulate Size Distribution  
 0.3 - 10.0  $\mu\text{m}$ , 9-Day Average  
 8-23, 25, 28, 11-29, 12-1, 4, 1972, and  
 2-5, 6, 15, 1973  
 Unit: Numbers  $\times 1,000/\text{m}^3$   
 $(8,000,000/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	5,032	7,097	11,226	19,484	36,000
Minimum	4,000	5,032	7,097	11,226	19,484
Symbol	.....	.....	+++	000000	xxxxx
Frequency	0	0	13	8	2

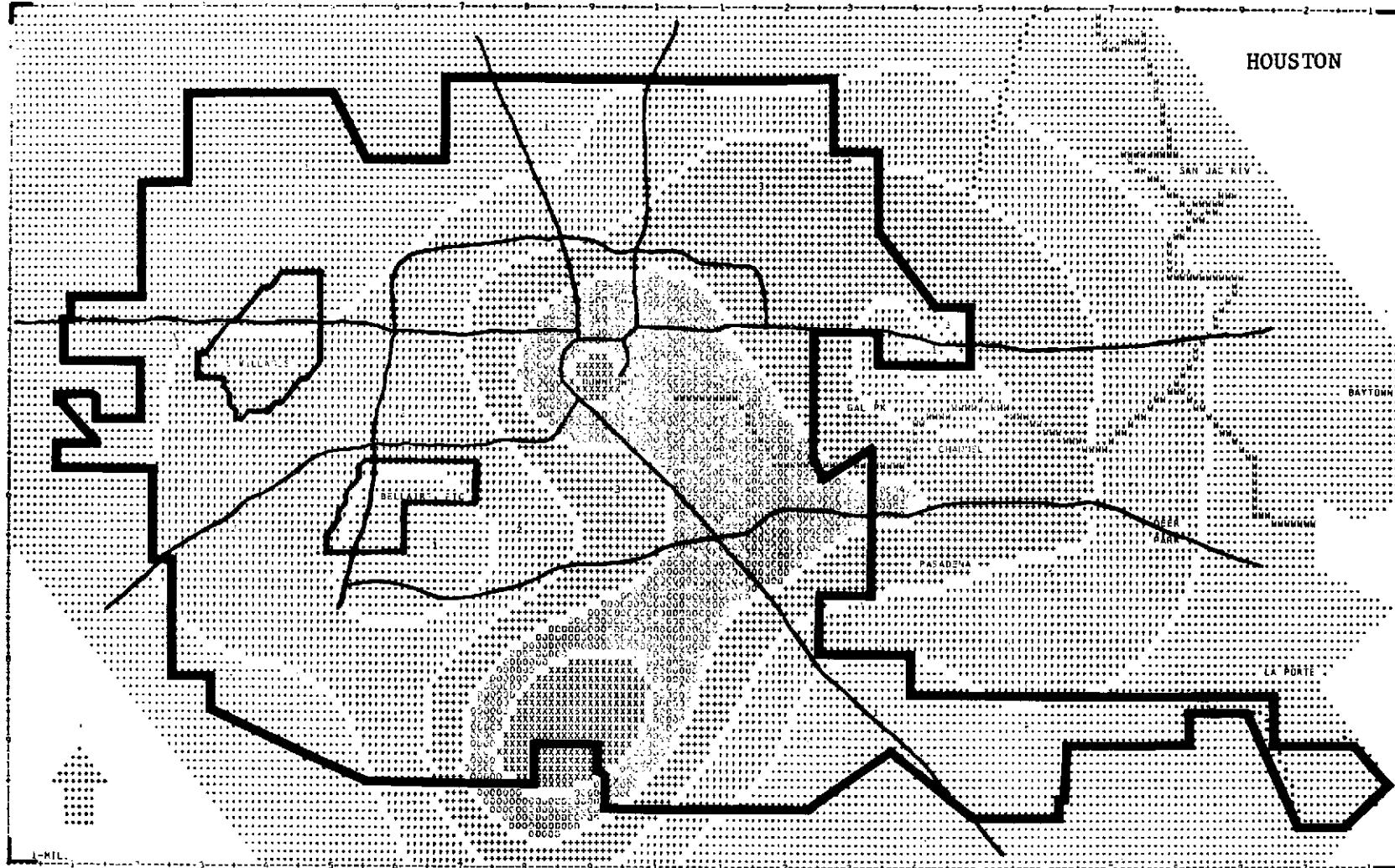


Figure 61. Suspended Particulate Matter  
 3-Day, 24-HR Average,  
 8-25, 11-29, 1972, and 2-15, 1973  
 Unit:  $\mu\text{g}/\text{m}^3$   
 $(42 \mu\text{g}/\text{m}^3 -$  Assumed Background)

Level	1	2	3	4	5
Maximum	54	68	82	96	110
Minimum	40	54	68	82	96
Symbol	....	,,,	+++	00000	xxxxx
Frequency	14	3	4	2	2

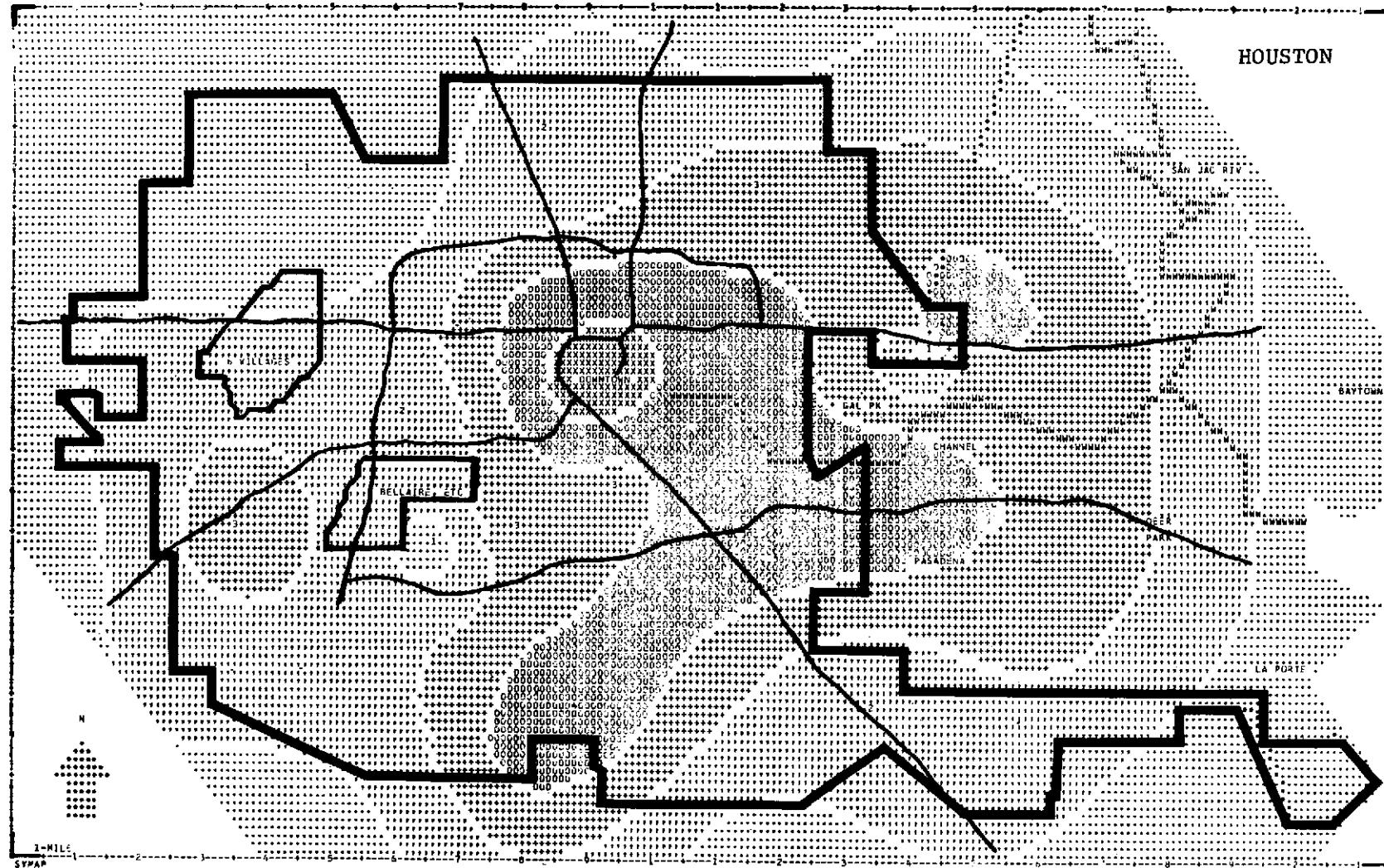


Figure 62. Suspended Particulate Matter  
7-Day, 24-HR Average  
8-19, 25, 31, 11-29, 12-5, 1972 and  
2-9, 15, 1973  
Unit:  $\mu\text{g}/\text{m}^3$   
(47  $\mu\text{g}/\text{m}^3$  - Assumed Background)

Level	1	2	3	4	5
Maximum	54	68	82	96	110
Minimum	40	54	68	82	96

## C. DATA ANALYSIS AND RESULTS

### 1. The Regression Analysis and the Power Law of Suspended Particulate Size Distribution Data in Houston

Based on the concept of a self-preserving particle size distribution, it can be described by a simple power law<sup>12, 13</sup> as follows:

$$N = N_0 S^{-m} \quad (1)$$

where  $N$  is the number of particles per  $m^3$  with size  $S \mu\text{m}$ ,

$N_0$  is the number of particles per  $m^3$  with size  $1 \mu\text{m}$ ,

$S$  is the size of particles in  $\mu\text{m}$ , and

$m$  is approximately constant.

When taking the logarithms on both sides, the equation (1) becomes:

$$\log N = \log N_0 - m \log S \quad (2)$$

By plotting  $\log N$  vs.  $\log S$ , the intercept and slope yield  $\log N_0$  and  $-m$  respectively if the power relation is valid. The logarithmic equation (2) can be reduced to a simpler form:  $y = a_0 + a_1 x$  (3)

where  $y = \log N$ ,  $a_0 = \log N_0$ ,  $x = \log S$ , and  $a_1 = -m$ . In order to test the data against power law, the linear regression analysis has been performed on  $y$  and  $x$ .

In linear regression analysis<sup>14</sup>, how well one variable ( $y$ ) may be explained by a group of other variables ( $x$ ) can be described. It is based on the method of the least squares for a 'best fitting' line. Least squares method estimates:

$$a_1 = \frac{n \sum xy - (\sum x) \cdot (\sum y)}{n \sum x^2 - (\sum x)^2} \quad (4)$$

$$a_0 = \frac{\sum y - a_1 \sum x}{n} \quad (5)$$

The coefficient of correlation,

$$r = \frac{n\sum xy - (\sum x) \cdot (\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2] \cdot [n\sum y^2 - (\sum y)^2]}} \quad (6)$$

is a very good measure of the linear correlation between two variables. If  $r = \pm 1$ , then there is a perfect linear relationship between  $x$  and  $y$ . If  $r = 0$ , there is no linear relationship. The standard error of estimate is

$$s_{y.x} = \frac{1}{n} \sqrt{n\sum y^2 - (\sum y)^2 - \frac{(n\sum xy - \sum x\sum y)^2}{n\sum x^2 - (\sum x)^2}} \quad (7)$$

which is a measure of the scatter about the regression line.

The regression analysis has been applied to the data (Table 23 - 26) from stations 2, 4, 8, and 16 which were chosen to represent commercial, semi-rural, residential, and industrial areas respectively. The results are shown in Tables 27 - 30. It shows that the readings of  $-r$  are from 0.923 to 0.986 on August 23, 25, and 28, 1972 except for the 0.823 reading for station 4 on August 25, 1972. From Table 23, it was found that the number of particles in 1.4 - 3.0  $\mu\text{m}$  size was larger than that of the particles in 0.7 - 1.4  $\mu\text{m}$  for station 4 on August 25, 1972. This somewhat anomalous distribution could explain the relatively low  $-r$  value. The readings of  $-r$  are: from 0.934 to 0.995 on October 4, 5, and 6, 1972; from 0.935 to 0.999 on November 29, December 1, and 4, 1972; from 0.897 to 0.995 on February 5, 6, and 15, 1973. The ranges of  $s_{y.x}$  are: from 0.09 to 0.247 on August 23, 25, and 28, 1972; from 0.068 to 0.298 on October 4, 5, and 6, 1972; from 0.037 to 0.269 on November 29, December 1, and 4, 1972; and from 0.056 to 0.350 on February 5, 6, and 15, 1973. From these results, the power law as applied to suspended particulate size distribution is shown to be a good descriptor.

Table 23. Suspended Particulate Size Distribution Data of Four Stations on August 23, 25, and 28, 1972.

Number of Particles per m<sup>3</sup>

Station	Date	0.3-0.5 μm	0.5-0.7 μm	0.7-1.4 μm	1.4-3.0 μm	3.0-10.0 μm
2	8-23-72	135,565,683	51,199,500	8,025,963	4,464,950	564,960
	8-25-72	3,082,740	1,820,231	1,450,535	1,300,997	133,472
	8-28-72	5,663,724	2,481,764	1,361,200	1,307,529	180,081
	3-day Average	48,104,049	18,500,498	3,612,566	2,357,825	292,838
4	8-25-72	2,269,903	1,585,949	1,489,199	1,981,774	152,010
	8-28-72	4,347,191	1,691,349	781,234	554,367	82,979
	2-day Average	3,308,547	1,638,649	1,135,217	1,268,070	117,494
8	8-23-72	3,771,638	2,436,390	764,462	694,901	118,289
	8-28-72	3,515,817	1,282,812	787,413	511,289	105,930
	2-day Average	3,643,727	1,859,601	775,937	603,095	112,109
16	8-23-72	9,292,886	6,002,700	2,206,522	1,475,252	176,550
	8-25-72	30,798,618	18,135,040	9,161,709	7,298,224	230,574
	8-28-72	5,170,267	1,818,642	846,381	944,366	88,275
	3-day Average	15,087,257	8,652,127	4,071,537	3,239,281	165,133

Table 24. Suspended Particulate Size Distribution Data of Four Stations on October 4, 5, and 6, 1972.

Number of Particles per  $\text{m}^3$

Station	Date	0.3-0.5 $\mu\text{m}$	0.5-0.7 $\mu\text{m}$	0.7-1.4 $\mu\text{m}$	1.4-3.0 $\mu\text{m}$	3.0-10.0 $\mu\text{m}$
2	10-4-72	10,378,757	3,083,181	1,155,520	722,531	102,664
	10-5-72	23,588,492	14,518,854	10,645,877	6,305,218	205,857
	10-6-72	7,195,472	2,927,552	1,133,186	534,152	73,975
	3-day Average	13,720,907	6,843,196	4,311,528	2,520,634	127,499
4	10-4-72	12,209,668	3,763,605	1,341,427	474,213	37,693
	10-5-72	17,140,004	7,965,406	5,229,058	1,874,696	59,586
	10-6-72	4,984,271	1,675,636	619,073	314,436	40,695
	3-day Average	11,444,648	4,468,216	2,396,519	887,782	45,991
8	10-4-72	18,043,763	5,934,552	2,542,585	1,095,228	82,184
	10-5-72	31,081,098	21,674,073	11,796,983	4,928,305	106,460
	10-6-72	4,962,997	1,614,991	726,680	361,486	44,667
	3-day Average	18,029,286	9,741,205	5,022,083	2,128,340	77,770
16	10-4-72	9,224,296	2,597,404	875,600	401,475	37,958
	10-5-72	17,264,736	6,721,788	3,521,290	2,655,047	41,842
	10-6-72	4,969,706	1,658,864	647,056	280,273	27,895
	3-day Average	10,486,246	3,659,352	1,681,315	1,112,265	35,899

Table 25. Suspended Particulate Size Distribution Data of Four Stations on November 29, December 1, and 4, 1972.

Number of Particles per m<sup>3</sup>

Station	Date	0.3-0.5 μm	0.5-0.7 μm	0.7-1.4 μm	1.4-3.0 μm	3.0-10.0 μm
2	11-29-72	8,810,022	4,331,301	1,349,195	502,285	62,675
	12-1-72	7,281,275	2,538,613	672,656	453,027	128,175
	12-5-72	17,565,666	9,345,851	4,731,187	2,680,029	88,275
	3-day Average	11,218,988	5,405,255	2,251,013	1,211,780	93,042
4	11-29-72	13,033,274	3,636,754	1,192,772	270,475	28,248
	12-1-72	10,542,683	4,381,618	1,802,752	661,003	72,209
	12-5-72	21,720,240	12,655,810	9,259,871	3,026,597	71,679
	3-day Average	15,098,733	6,891,394	4,085,132	1,319,358	57,379
8	11-29-72	5,881,763	2,431,623	1,437,823	594,797	38,488
	12-1-72	4,373,850	1,438,000	370,402	131,530	13,771
	12-5-72	17,233,222	8,123,419	6,232,215	3,297,071	55,437
	3-day Average	9,162,945	3,997,681	2,680,147	1,341,133	35,899
16	11-29-72	2,183,570	921,768	324,322	106,989	12,712
	12-1-72	8,616,699	3,103,219	790,591	302,254	37,076
	12-5-72	16,910,312	9,016,585	4,308,526	1,256,860	36,193
	3-day Average	9,236,861	4,347,191	1,807,813	555,368	28,660

Table 26. Suspended Particulate Size Distribution Data of Four Stations on February 5, 6, and 15, 1973

Number of Particles per m<sup>3</sup>

Station	Date	0.30-0.5 $\mu\text{m}$	0.5-0.7 $\mu\text{m}$	0.7-1.4 $\mu\text{m}$	1.4-3.0 $\mu\text{m}$	3.0-10.0 $\mu\text{m}$
2	2-5-73	1,747,492	1,602,015	645,290	503,168	90,041
	2-6-73	4,337,657	2,617,883	1,246,267	708,142	131,883
	2-15-73	5,148,198	1,667,338	516,232	228,279	33,545
	3-day Average	3,744,448	1,962,412	802,596	479,863	85,156
4	2-5-73	1,306,647	1,076,602	697,373	412,951	72,386
	2-6-73	7,926,036	6,360,037	4,955,405	3,015,827	133,648
	2-15-73	2,764,597	1,092,138	257,233	101,869	11,652
	3-day Average	3,999,093	2,842,956	1,970,004	1,176,882	72,562
8	2-5-73	1,169,644	1,108,028	1,021,165	763,579	111,403
	2-6-73	15,997,902	12,948,354	6,979,198	3,070,381	145,124
	2-15-73	2,981,223	999,083	173,372	92,159	8,651
	3-day Average	6,716,256	5,018,728	2,724,579	1,308,706	88,393
16	2-5-73	2,971,160	2,218,351	846,910	738,156	79,448
	2-6-73	43,642,807	27,965,520	15,682,230	10,774,493	126,057
	2-15-73	3,176,664	810,011	278,243	99,927	12,535
	3-day Average	16,596,877	10,331,294	5,602,461	3,870,859	72,680

Table 27. Linear Regression Analysis of Four Stations Data on August 23, 25, and 28, 1972.

Station	Date	$N_o$ (#/ $m^3$ )	$\log N_o$ or $a_o$	-m or - $a_1$	-r	$S(y,x)$
2	8-23-72	17,446,400	7.242	1.905	0.983	0.152
	8-25-72	1,389,966	6.143	1.014	0.927	0.176
	8-28-72	1,794,538	6.254	1.107	0.962	0.136
	3-day Average	7,313,739	6.864	1.750	0.983	0.141
4	8-25-72	1,362,350	6.134	0.832	0.823	0.247
	8-28-72	1,071,703	6.030	1.308	0.983	0.106
	2-day Average	1,286,207	6.109	1.049	0.923	0.188
8	8-23-72	1,215,361	6.085	1.189	0.977	0.111
	8-28-72	963,976	5.984	1.143	0.981	0.097
	2-day Average	1,098,230	6.041	1.172	0.984	0.091
16	8-23-72	2,848,018	6.455	1.377	0.986	0.101
	8-25-72	9,314,491	6.969	1.636	0.943	0.247
	8-28-72	1,281,119	6.108	1.286	0.952	0.178
	3-day Average	4,562,814	6.659	1.513	0.958	0.196

Table 28. Linear Regression Analysis of Four Stations Data on October 4, 5, and 6, 1972.

Station	Date	$N_o$ (#/ $m^3$ )	$\log N_o$ or $a_o$	-m or - $a_1$	-r	s (y.x)
2	10-4-72	1,810,529	6.258	1.528	0.983	0.123
	10-5-72	8,181,224	6.913	1.597	0.934	0.262
	10-6-72	1,479,163	6.170	1.573	0.995	0.068
	3-day Average	3,958,356	6.598	1.569	0.961	0.194
4	10-4-72	1,694,245	6.229	1.981	0.995	0.083
	10-5-72	3,944,519	6.596	1.937	0.968	0.217
	10-6-72	881,442	5.945	1.626	0.991	0.094
	3-day Average	2,236,308	6.350	1.883	0.985	0.144
8	10-4-72	3,027,180	6.481	1.825	0.991	0.107
	10-5-72	8,786,777	6.944	1.974	0.953	0.270
	10-6-72	934,623	5.971	1.580	0.990	0.096
	3-day Average	4,384,006	6.642	1.877	0.972	0.196
16	10-4-72	1,280,286	6.107	1.853	0.991	0.108
	10-5-72	3,557,917	6.551	1.974	0.943	0.298
	10-6-72	832,383	5.920	1.763	0.993	0.087
	3-day Average	1,953,207	6.291	1.873	0.967	0.212

Table 29. Linear Regression Analysis of Four Stations Data on November 29, December 1, and 4, 1972.

Station	Date	$N_o$ (#/ $m^3$ )	$\log N_o$ or $a_o$	-m or - $a_1$	-r	s (y.x)
2	11-29-72	1,725,494	6.237	1.751	0.998	0.043
	12-1-72	1,330,395	6.124	1.368	0.967	0.154
	12-4-72	4,494,847	6.653	1.795	0.962	0.218
	3-day Average	2,630,182	6.420	1.639	0.986	0.117
4	11-29-72	1,464,226	6.166	2.142	0.998	0.061
	12-1-72	2,054,332	6.313	1.732	0.997	0.057
	12-4-72	5,869,179	6.769	1.977	0.953	0.269
	3-day Average	3,278,903	6.516	1.924	0.979	0.171
8	11-29-72	1,333,076	6.125	1.709	0.982	0.140
	12-1-72	559,600	5.748	2.001	0.996	0.081
	12-4-72	4,501,150	6.653	1.911	0.935	0.313
	3-day Average	2,194,577	6.341	1.854	0.955	0.248
16	11-29-72	389,963	5.591	1.808	0.999	0.037
	12-1-82	1,220,035	6.086	1.899	0.995	0.082
	12-4-72	3,425,809	6.535	2.153	0.978	0.197
	3-day Average	1,782,762	6.238	2.022	0.991	0.119

Table 30. Linear Regression Analysis of Four Stations Data on February 5, 6, and 15, 1973.

Station	Date	$N_o$ (#/ $m^3$ )	$\log N_o$ or $a_o$	$-m$ or $-a_1$	$-r$	$s$ ( $y \cdot x$ )
2	2-5-73	794,900	5.900	1.057	0.977	0.100
	2-6-73	1,444,421	6.160	1.217	0.994	0.056
	2-15-73	790,827	5.898	1.724	0.992	0.095
	3-day Average	1,051,027	6.022	1.304	0.993	0.066
4	2-5-73	641,580	5.807	1.022	0.974	0.102
	2-6-73	3,598,381	6.556	1.397	0.920	0.255
	2-15-73	403,868	5.606	1.916	0.995	0.081
	3-day Average	1,618,156	6.209	1.371	0.946	0.202
8	2-5-73	794,664	5.900	0.807	0.897	0.171
	2-6-73	5,582,183	6.747	1.661	0.961	0.205
	2-15-73	352,398	5.547	2.012	0.987	0.140
	3-day Average	2,369,608	6.375	1.522	0.969	0.166
16	2-5-73	1,100,990	6.042	1.246	0.969	0.137
	2-6-73	12,646,328	7.102	1.967	0.924	0.350
	2-15-73	398,341	5.600	1.883	0.992	0.101
	3-day Average	4,897,216	6.690	1.829	0.935	0.299

The linear regression plots of the four stations on August 28, 1973, are shown as examples in Figures 63 - 66. The logN vs logS plots of the three-day average of suspended particulate size distribution of four stations in the four time periods are shown in Figures 67 - 70. The  $\log N_0$ ,  $-m$ , and percentage of particles in  $0.3 - 0.7 \mu\text{m}$  are listed in Table 31. In period of August, 1972, the line of station 2 (commercial area) and the line of station 16 (industrial area) are close to each other while the line of station 4 (semi-rural area) is closer to the line of station 8 (residential area) than other lines as shown in Figure 67. From Table 31,  $N_0$  in August, 1972 period decreased in the order of: station 2, station 16, station 4, and station 8. Similarly  $-m$  in August, 1972 period decreased except for station 4. A smaller  $-m$  in station 4 than that of station 8 indicated that station 8 had a higher percentage of particles in  $0.3 - 0.7 \mu\text{m}$  size range than that of station 4. This was confirmed by the data and was reasonable since a residential area has more human activity and hence the percentage of particles in the lower size range would be higher.

From Table 31 and Figures 68 - 70, the pattern in August, 1972 did not reappear in October, 1972, December, 1972, and February, 1973 periods. In order to see the seasonal variation, the plots of  $\log N_0$  vs stations,  $-m$  vs stations, and percentage of particles in  $0.3 - 0.7 \mu\text{m}$  vs stations were shown in Figures 71-73 respectively. It is an interesting phenomena that the trend in the period of August, 1972 was similar to that of the period of February, 1973, and while the trend in the period of October, 1972 was similar to that of the period of December, 1972. From Figure 73, both the August, 1972 and the February, 1973 periods, the percentage of particles in the  $0.3 - 0.7 \mu\text{m}$  range in the commercial area was higher than in the industrial area and the percentage in the residential area was higher than in the semi-rural area, while the opposite was true in the October, 1972 and the December, 1972 periods. Thus, the  $\log N_0$ ,  $-m$ , and percentage of particles in  $0.3 - 0.7 \mu\text{m}$  range could

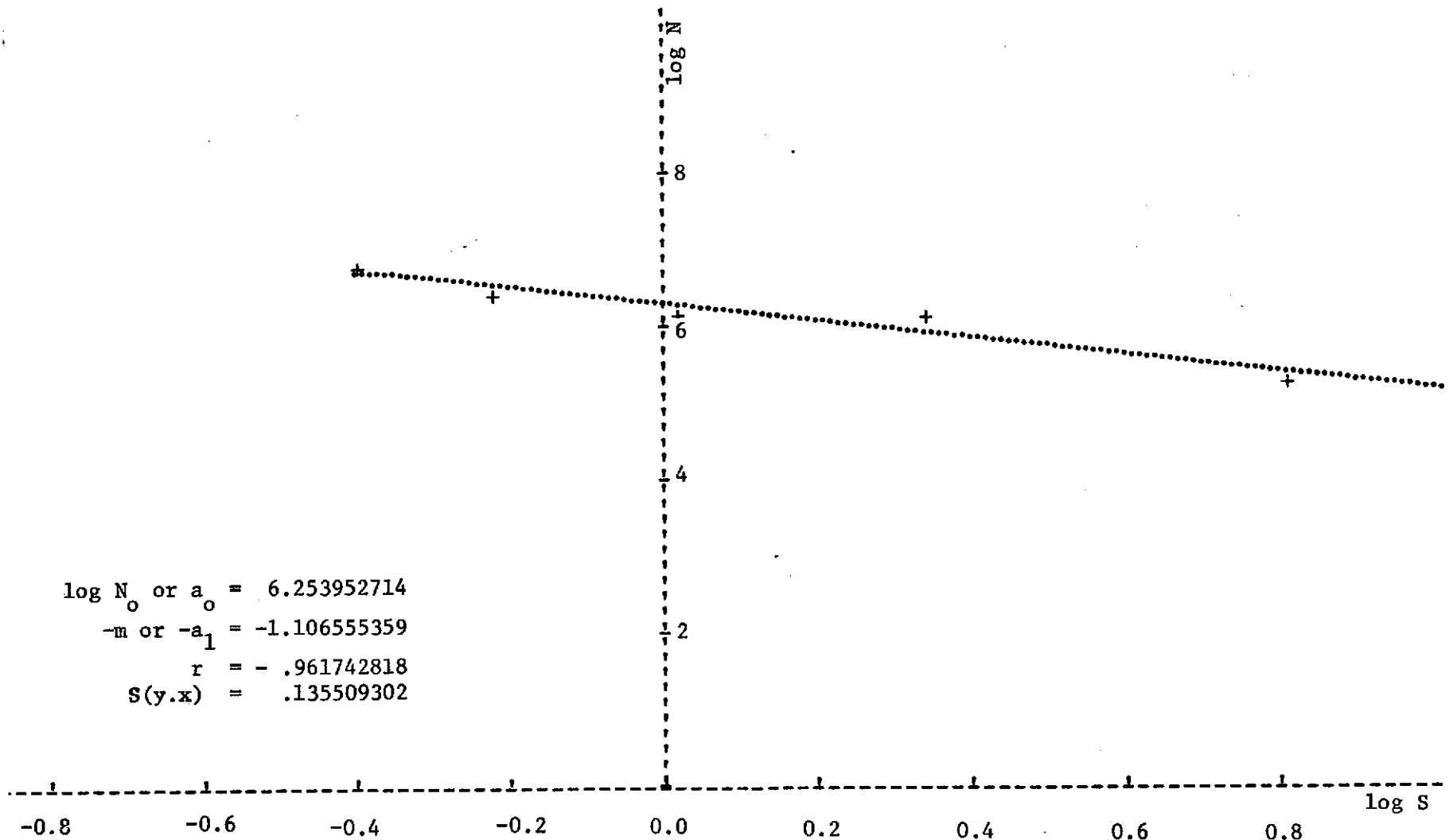


Figure 63. Linear Regression Analysis of Suspended Particulate Size Distribution of Station 2 on August 28, 1972.

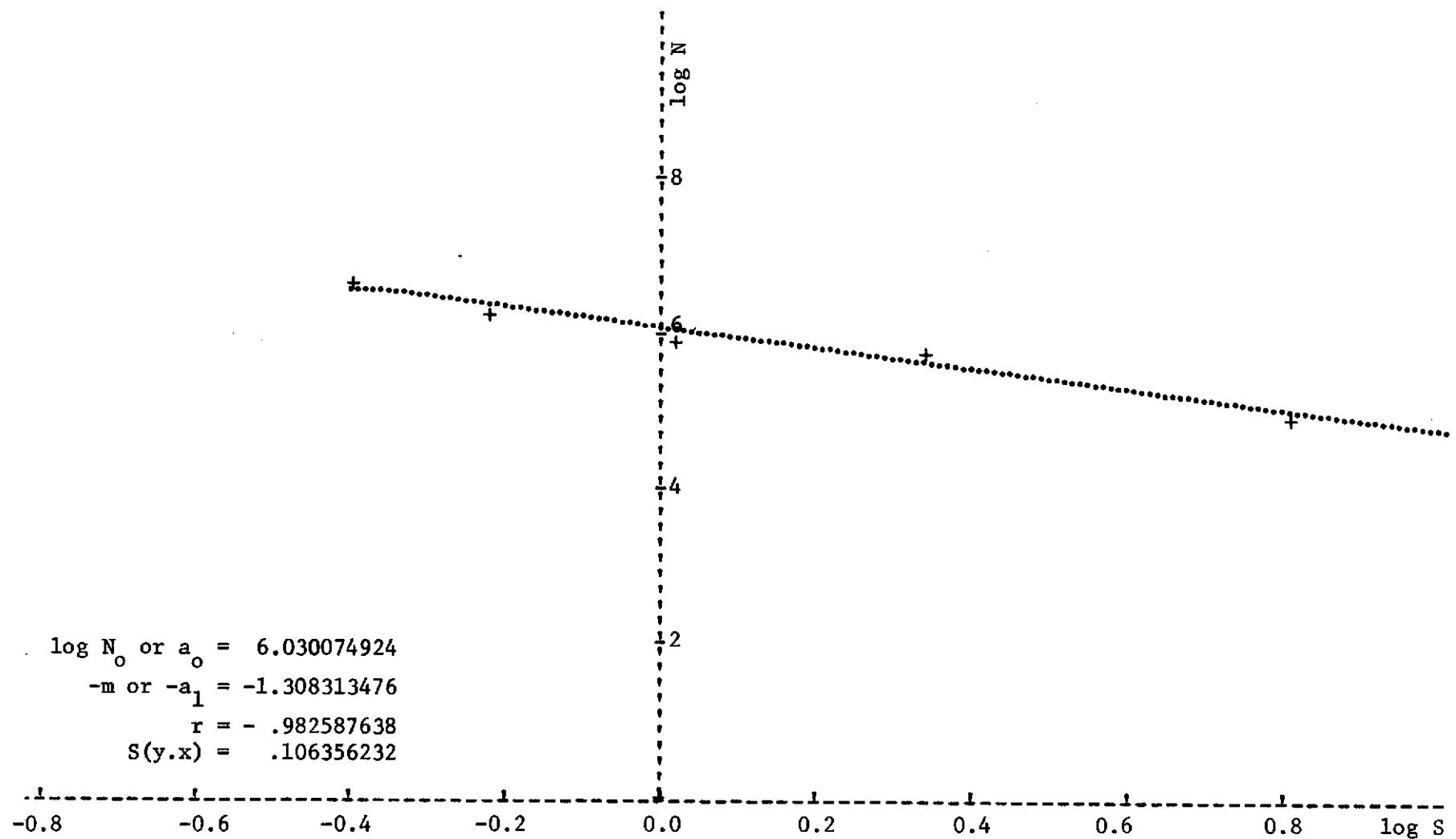


Figure 64. Linear Regression Analysis of Suspended Particulate Size Distribution of Station 4 on August 28, 1972.

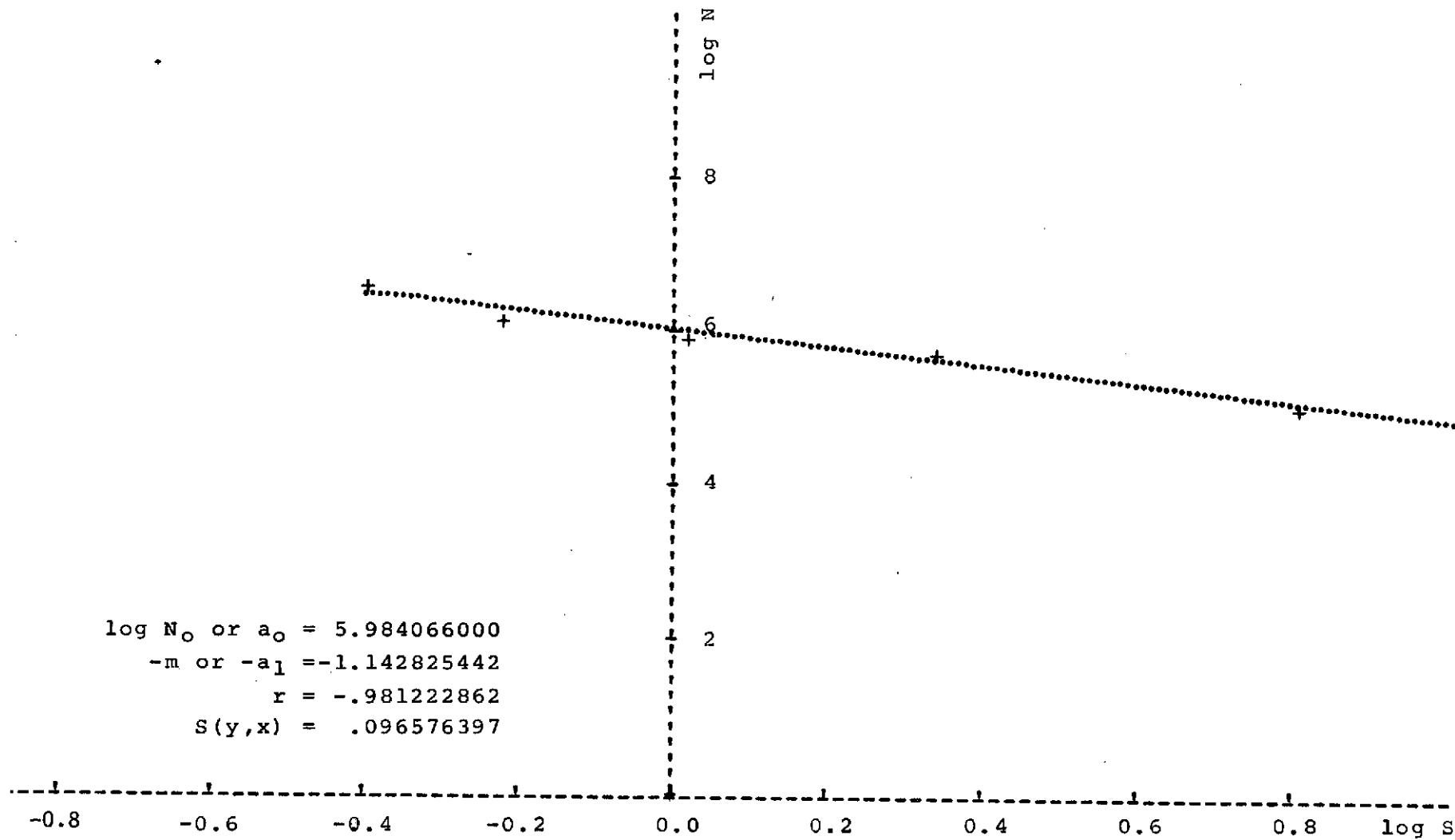


Figure 65. Linear Regression Analysis of Suspended Particulate Size Distribution of Station 8 on August 28, 1972.

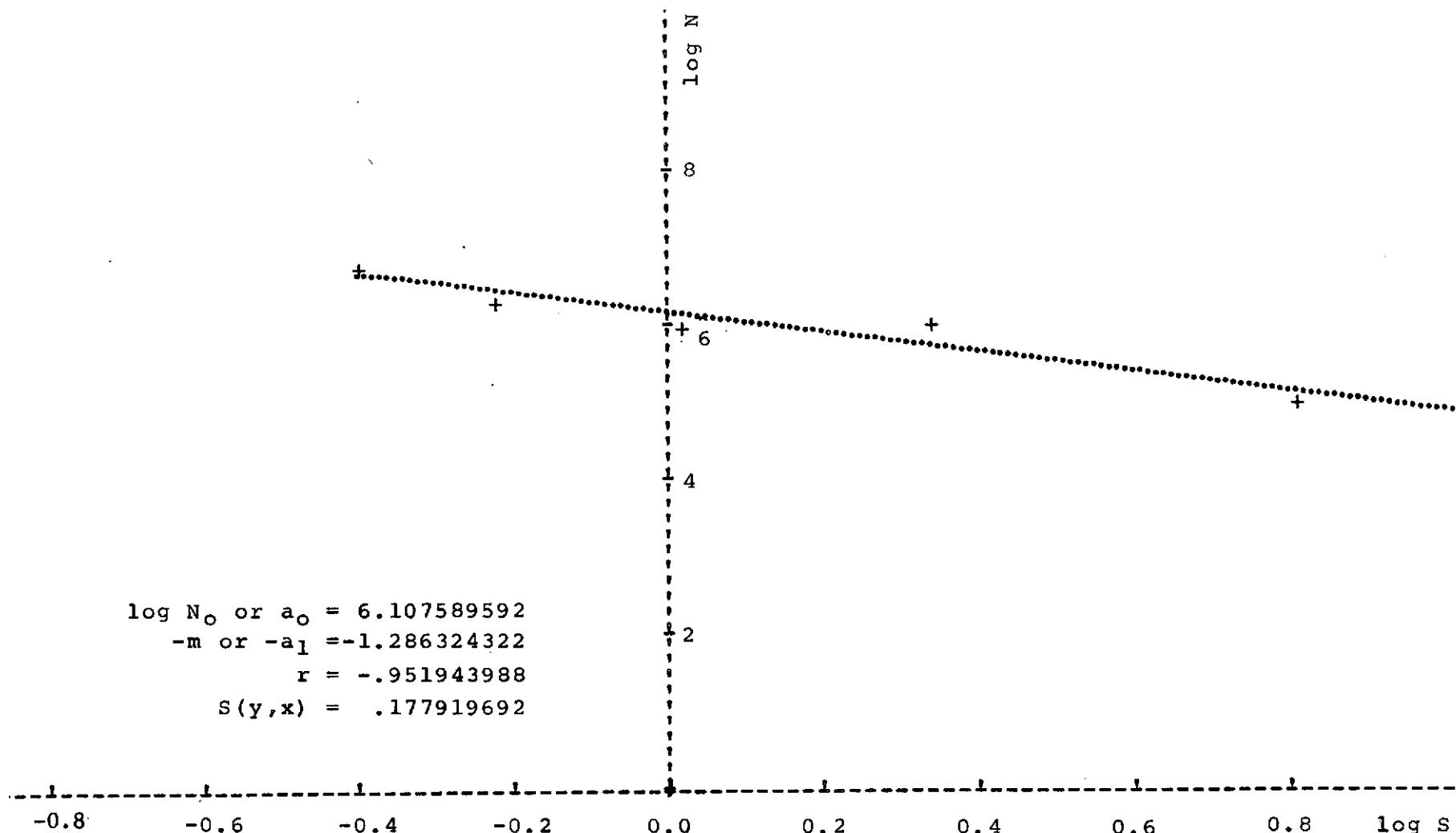


Figure 66. Linear Regression Analysis of Suspended Particulate Size Distribution of Station 16 on August 28, 1972.

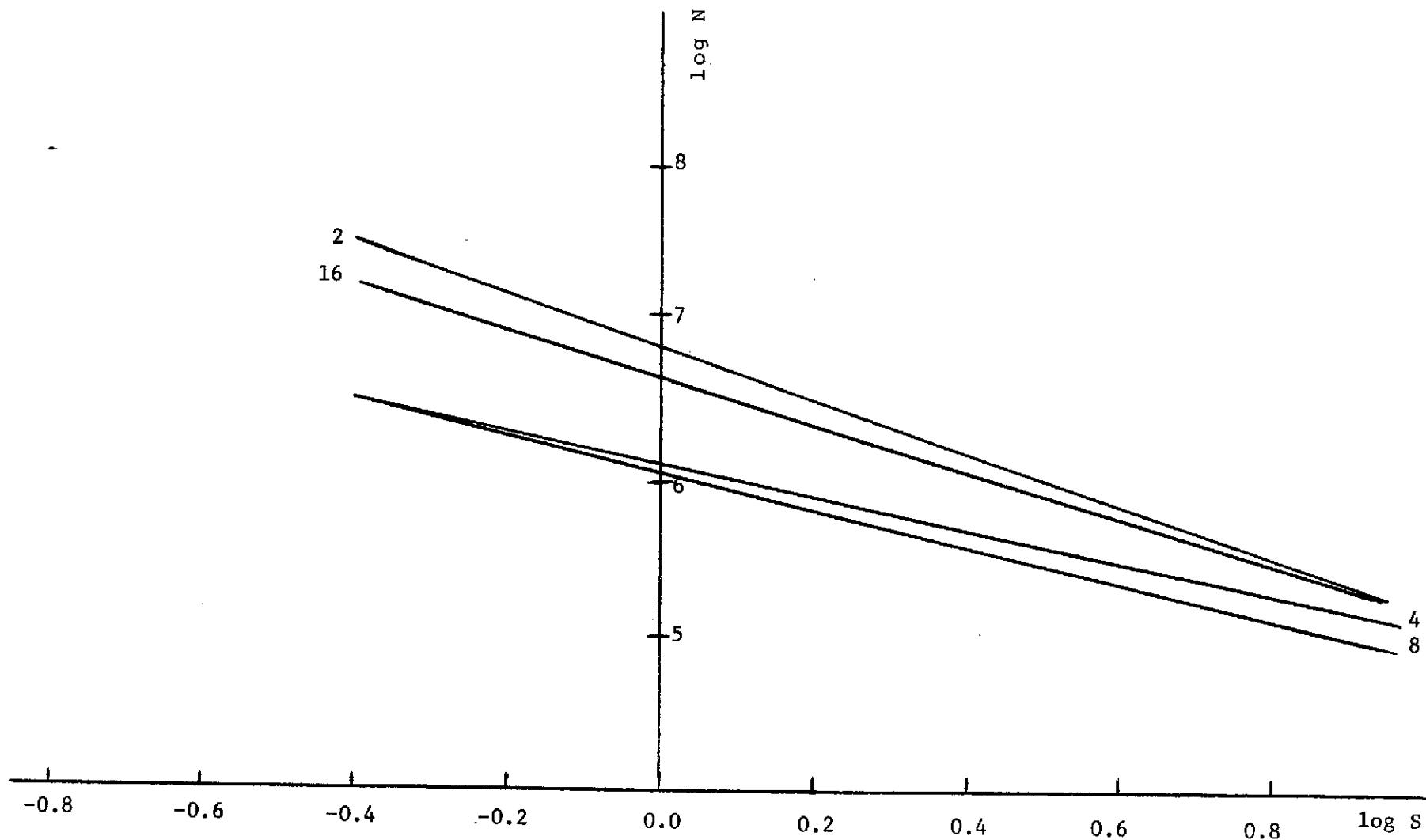


Figure 67.  $\log N$  vs  $\log S$  Plot of three -Day average of Suspended Particulate Size Distribution of Four Stations in Houston on August 23, 25, and 28, 1972.

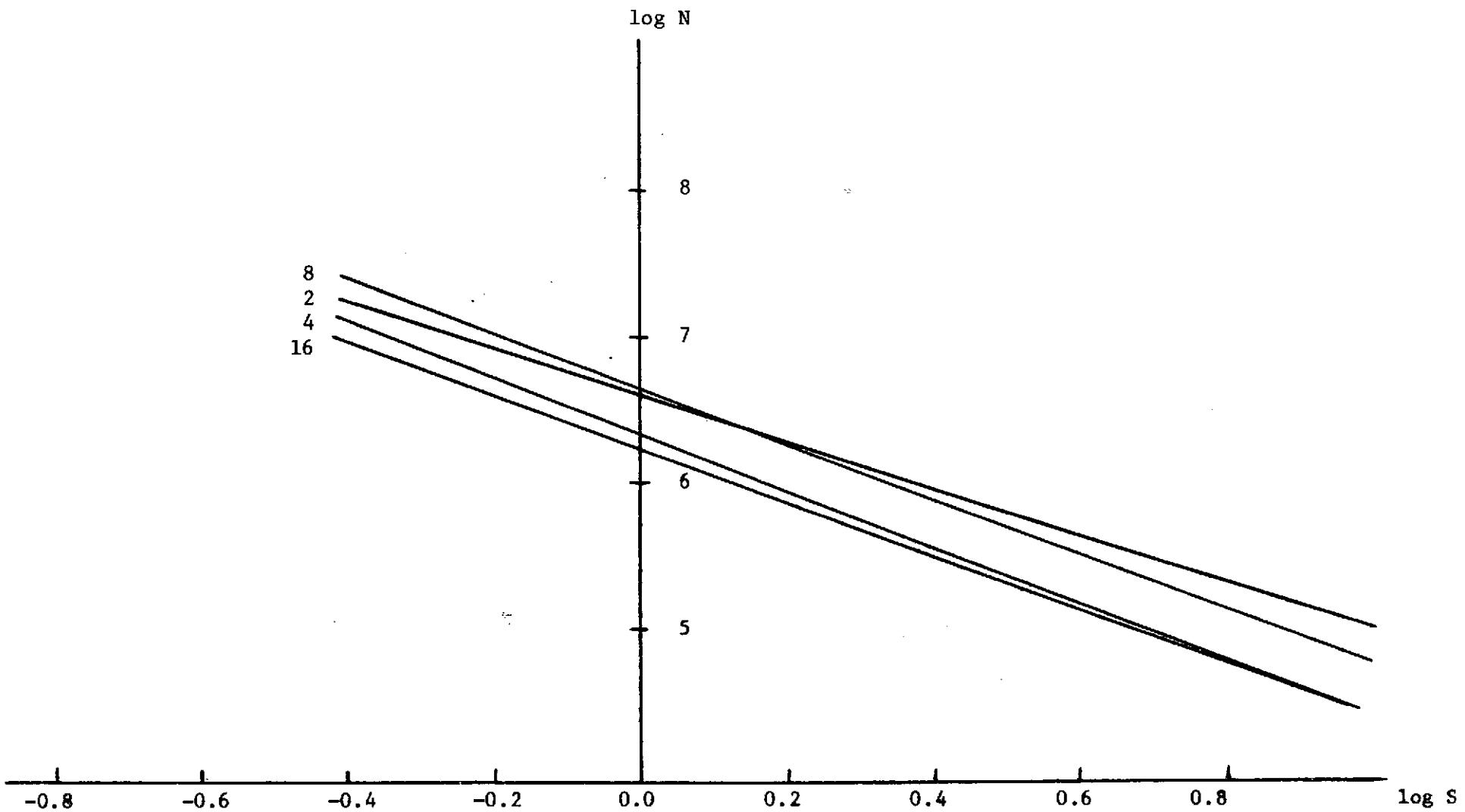


Figure 68.  $\log N$  vs  $\log S$  Plot of three - Day Average of Suspended Particulate Size Distribution of Four Stations in Houston on October 4, 5, and 6, 1972.

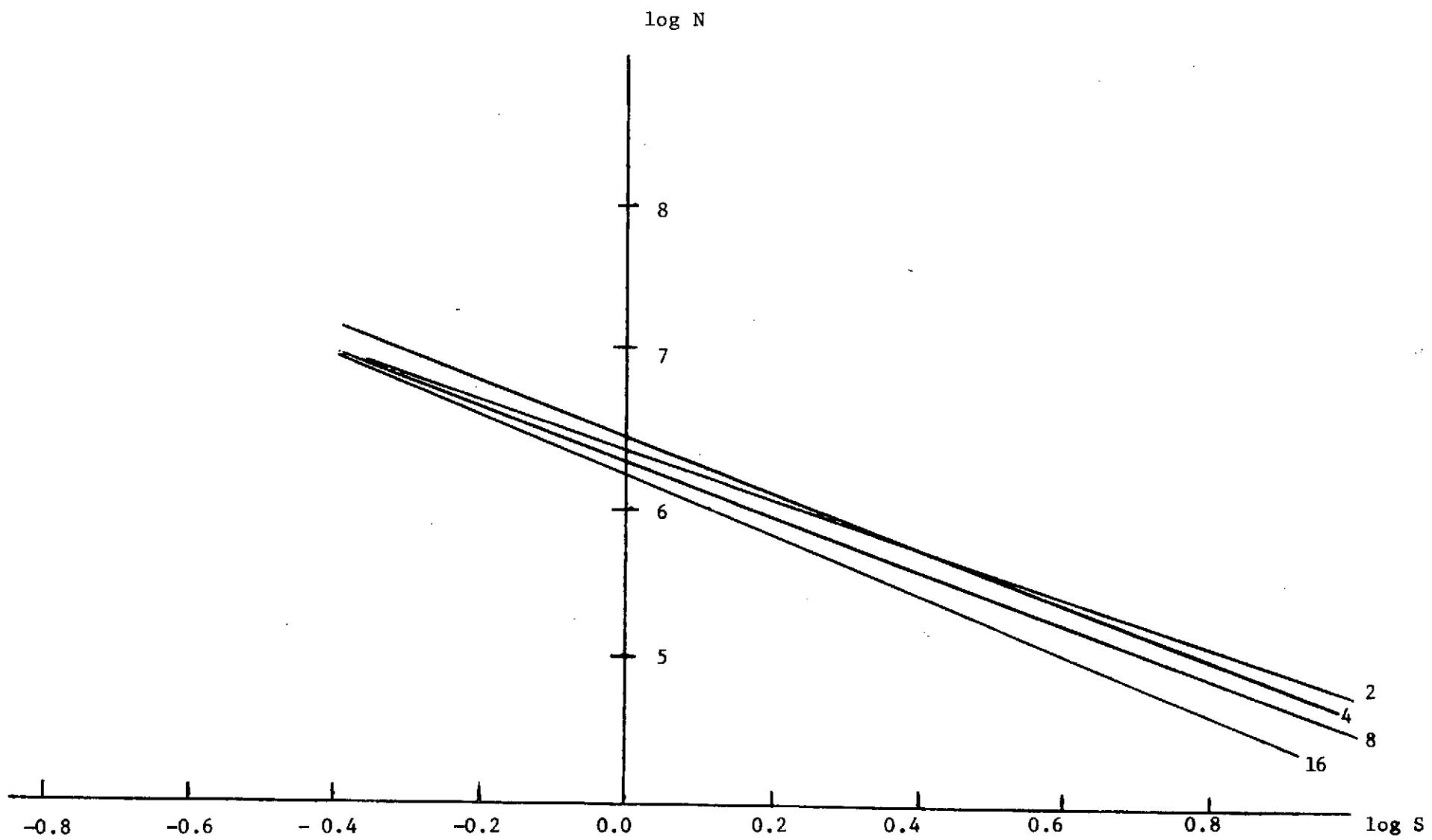


Figure 69.  $\log N$  vs  $\log S$  Plot of three -day average of Suspended Particulate Size Distribution of Four Stations in Houston on November 29, December 1, and 4, 1972.

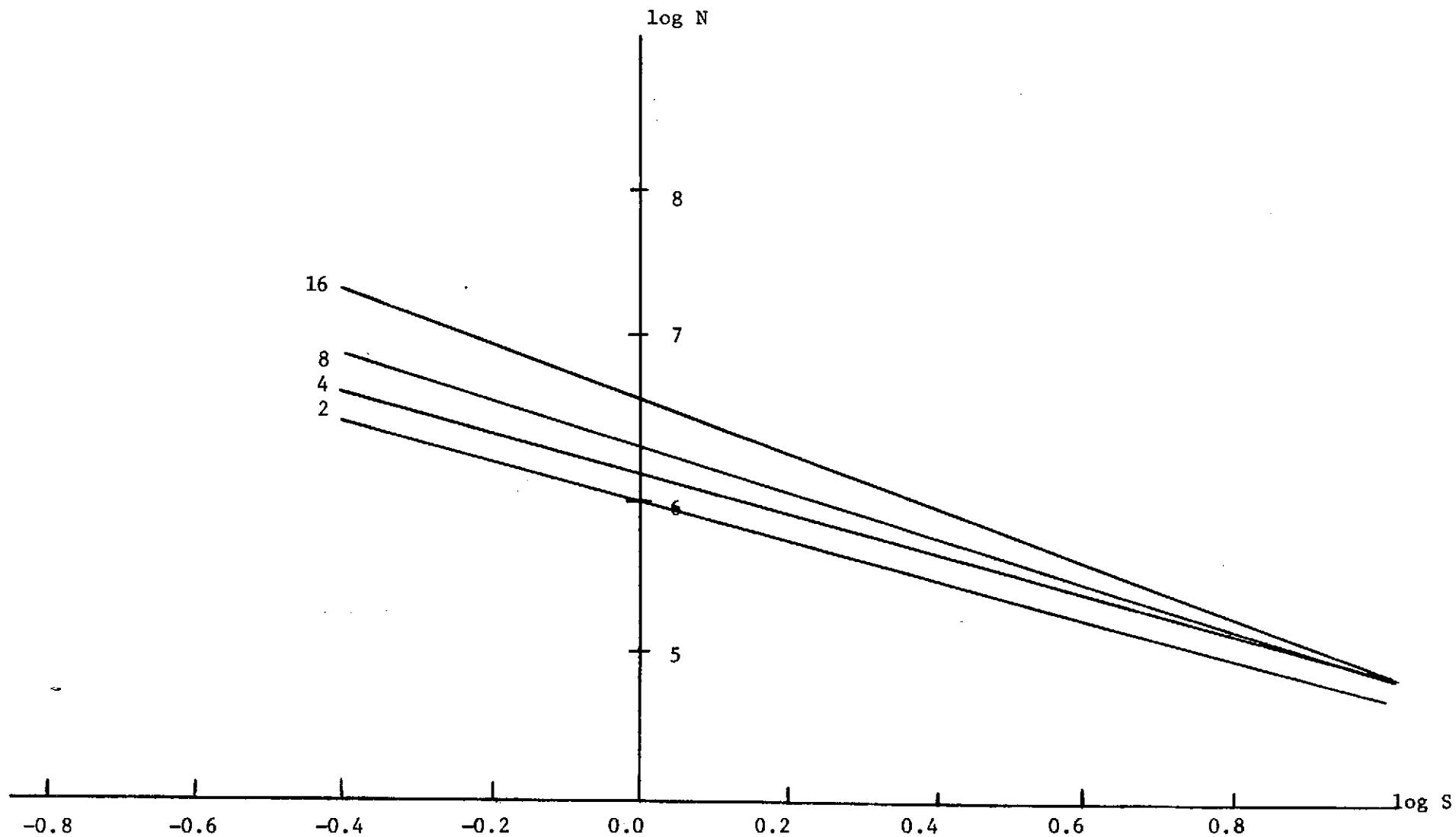


Figure 70.  $\log N$  vs  $\log S$  Plot of three - day Average of Suspended Particulate Size Distribution of Four Stations in Houston on February 5, 6, and 15, 1973.

Table 31. Characteristics of Particle Size Distribution for Four Stations in Houston

Station	Represented Area	log N <sub>0</sub>				-m				Percentage of Particles in 0.3-0.7 $\mu\text{m}$			
		8-72	10-72	12-72	2-73	8-72	10-72	12-72	2-73	8-72	10-72	12-72	2-73
2	Commercial area	6.864	6.598	6.420	6.022	1.750	1.569	1.639	1.304	91.40	74.71	82.38	80.67
16	Industrial area	6.659	6.290	6.238	6.690	1.513	1.873	2.022	1.829	76.05	83.33	85.03	73.83
4	Semi-Rural area	6.109	6.350	6.516	6.209	1.049	1.883	1.924	1.371	66.25	82.69	80.10	68.00
8	Residential area	6.041	6.642	6.341	6.375	1.172	1.877	1.854	1.522	78.68	79.35	76.44	74.01

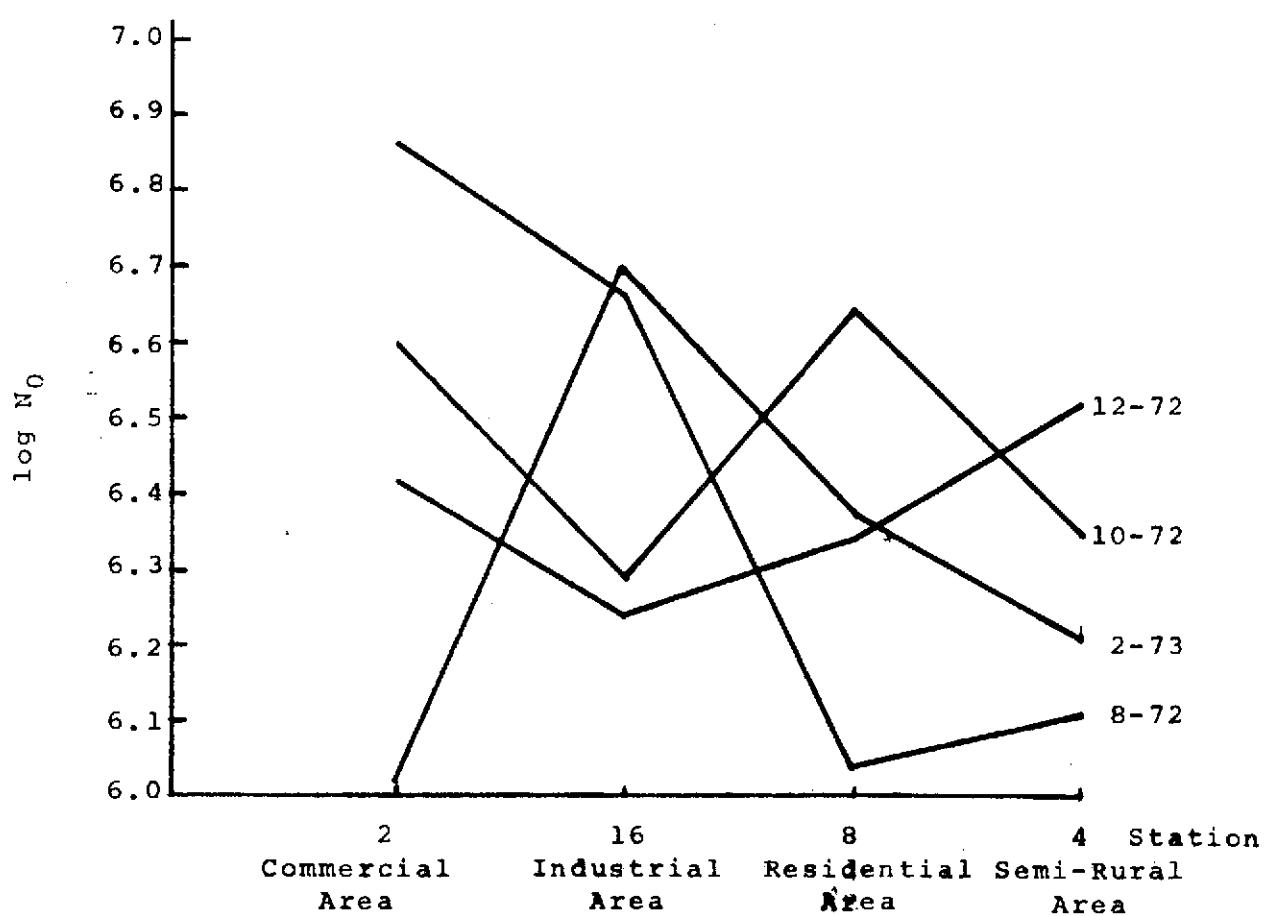
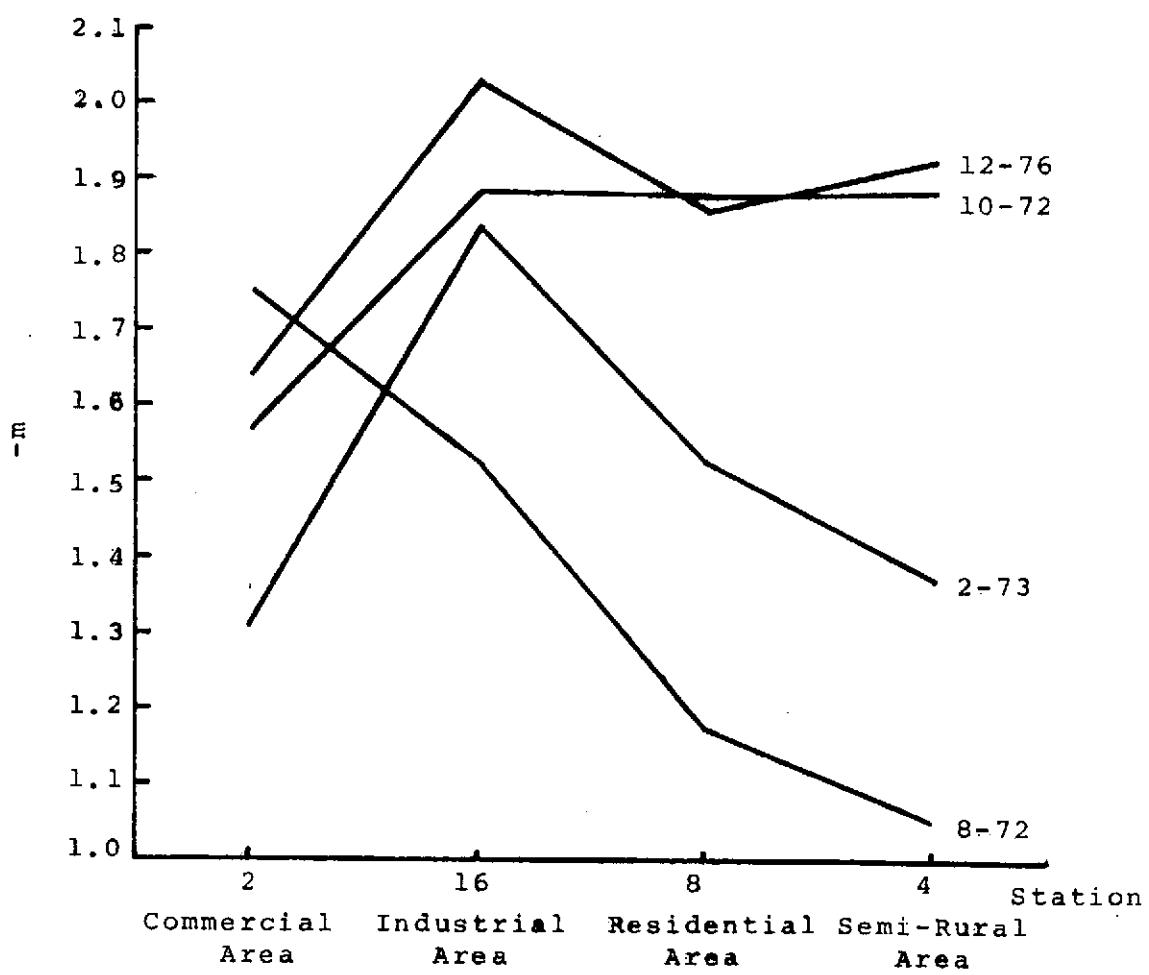


Figure 71.  $\log N_0$  vs Stations in Houston

Figure 72.  $-m$  vs Stations in Houston

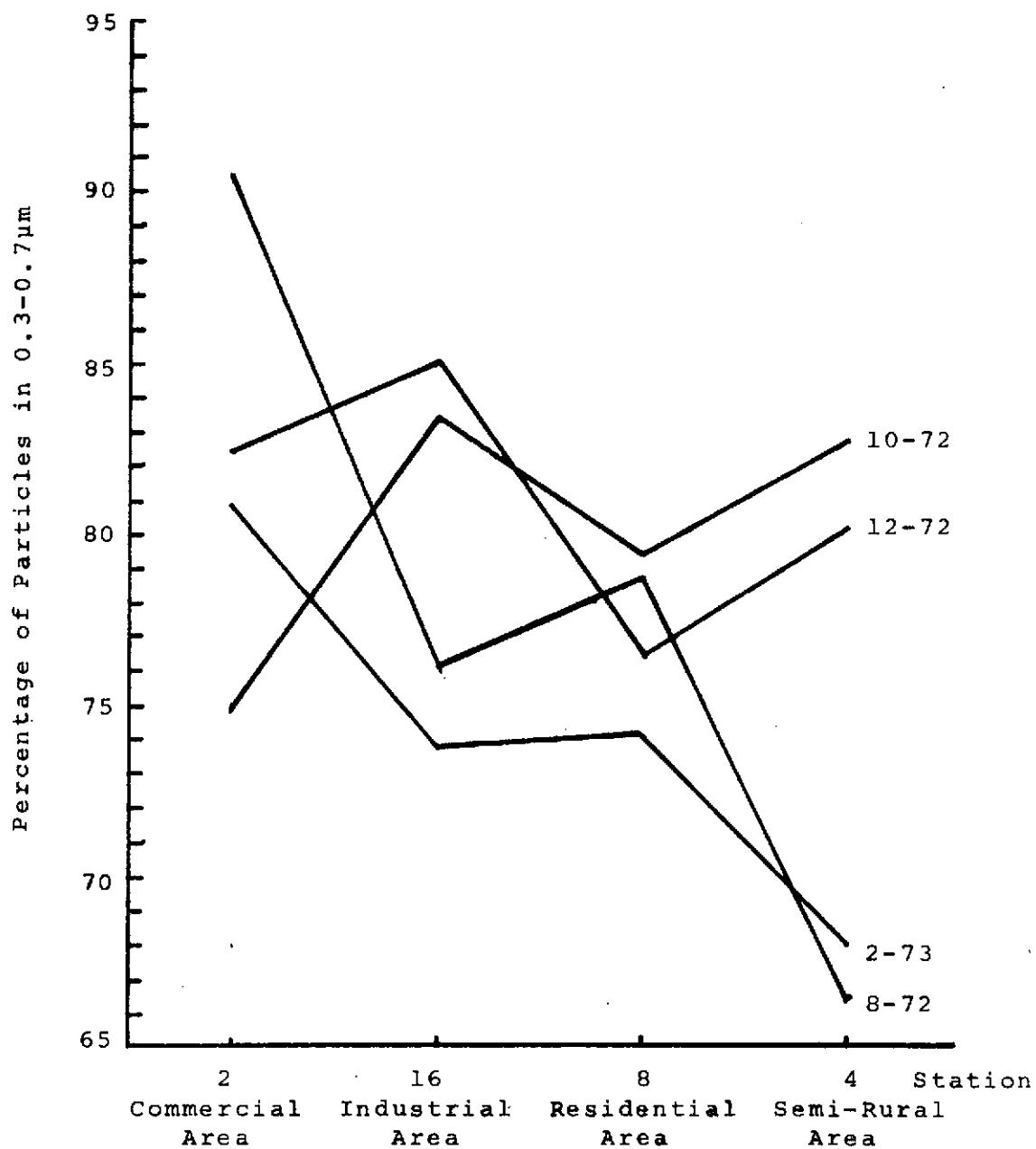


Figure 73. Percentage of Particles in  $0.3-0.7\mu\text{m}$  vs.  
Different Areas in Houston

characterize these four different stations and mark the seasonal variation as well.

## 2. The Isopleth Maps of Different Size Range Particles

In August, 1972 period, the distribution patterns for 0.3 - 0.7  $\mu\text{m}$ , 0.7 - 1.4  $\mu\text{m}$ , and 1.4 - 3.0  $\mu\text{m}$  size range particles were quite similar for both the one-day data, (Figures 15, 17, and 19) and the three-day data (Figures 16, 18, and 20). Only the distribution pattern for 3.0 - 10.0  $\mu\text{m}$  size range particles were different (Figures 21, 22).

But the distribution patterns for 0.3 - 0.7  $\mu\text{m}$ , 0.7 - 1.4  $\mu\text{m}$ , 1.4 - 3.0  $\mu\text{m}$ , and 3.0 - 10.0  $\mu\text{m}$  size range particles were all different for December 1972, February, 1973, and the average of August, 1972, December, 1972, and February, 1973 periods (Figures 27 - 34, 39 - 46, and 51 - 58). Since the particles of natural origin and man-made origin have their own characteristic size<sup>15</sup>, analyzing the particles source and meteorological data in Houston may explain the distribution pattern for particles of different size ranges.

Due to the predominating 0.3 - 0.7  $\mu\text{m}$  size range particles, its distribution pattern was almost identical to that of the 0.3 - 10.0  $\mu\text{m}$  size range particles or total particles (Figures 15, and 23; 16 and 24; 27 and 35; 28 and 36; 39 and 47; 40 and 48; 51 and 59; 52 and 60).

## 3. The Comparison of Suspended Particle Size and Mass Distribution in Houston

Both suspended particle size distribution and mass concentration were measured on August 25, 1972, November 29, 1972, and February 15, 1973. On August 25, 1972, the distribution pattern of 0.3 - 10.0  $\mu\text{m}$  range particles was very similar to that of the mass concentration (Figures 23, and 25). This was not true on November 29, 1972, February 15, and the average of August 25, 1972, November 29, 1972, and February 15, 1973 (Figures 35 and 37; 47 and 49; 59 and 61).

As to the three-day measurement, suspended particle size distribution and mass concentration were measured with only one day in common. Suspended particle size distribution data was taken on August 23, 25 and 28, 1972; November 29, December 1, and 4, 1972; and February 5, 6, and 15, 1973, while the suspended particle mass concentration data was taken on August 19, 25, and 31, 1972; November 29, December 5, and 9, 1972; and February 9, and 15, 1973. The distribution patterns of suspended particle size distribution (0.3 - 10.0  $\mu\text{m}$  size range) and mass distribution were similar in August, 1973 period (Figures 24, and 26) but not for the other period times (Figures 36, and 38; 48 and 50; and 60 and 62).

#### 4. The Meteorological Influence on the Suspended Particle Size and Mass Distribution in Houston

The wind data in Houston was collected from Hobby Airport through the Department of Public Health, City of Houston in order to analyze the meteorological influence on the suspended particle size and mass distribution in Houston. By using vector analysis, the one day resultant wind, three-day resultant wind, and the total resultant wind, were calculated from the hourly wind data and were shown in Tables 32 - 35. The wind data was summarized in Figure 74. Taking the resultant wind into consideration, the isopleth maps of suspended particle size and distribution were further examined.

On August 25, 1972 with a resultant wind of S - 5, the isopleth maps of suspended particle size and mass distributions were similar (Figures 23 and 25). On November 29, 1972 with a resultant wind of NNE - 9, the isopleth map of suspended particulate size distribution had a heavy concentration in southeast Houston (Figure 35) while the isopleth map of suspended particle mass distribution had a heavy concentration in central South Houston (Figure 37). On February 15, 1973 with a resultant wind of N - 9, the isopleth of suspended particle size distribution (Figure 47) was different from the isopleth map of suspended mass distribution (Figure 49) which also had a heavy concentration in central South Houston.

Table 32. Wind Data in Houston on October 4, 5, and 6, 1972

TIME	DATE		
	8-25-72	11-29-72	2-15-73
0800	S - 7	NE - 12	NNE - 11
0900	S - 6	NE - 12	NNE - 10
1000	SSW - 9	NE - 12	N - 8
1100	SSW - 10	ENE - 12	N - 6
1200	S - 5	NE - 12	NW - 12
1300	ESE - 7	ENE - 12	N - 8
1400	SSE - 5	ESE - 9	N - 10
1500	ENE - 6	NNW - 4	NNW - 12
1600	SW - 4	NNW - 9	NNE - 11
1700	SW - 8	N - 12	N - 12
One Day Resultant Wind	S - 5	NNE - 9	N - 9
Three Days Resultant Wind		NNE - 4	

Wind speed: knots

Table 33. Wind Data in Houston on October 4, 5, and 6, 1972

TIME	DATE		
	10-4-72	10-5-72	10-6-72
0800	NNE - 7	NE - 5	N -
0900	N - 9	NE - 5	N -
1000	NNE - 9	E - 7	NW - 3
1100	NE - 9	ESE - 8	NNW - 3
1200	NE - 8	E - 7	NW - 6
1300	NE - 6	SE - 6	NW - 7
1400	ENE - 12	E - 8	NW - 4
1500	ENE - 11	SE - 5	N - 4
1600	ESE - 11	SE - 9	NW - 10
1700	ESE - 9	E - 10	N - 6
One Day Resultant Wind	ENE - 7	E - 6	NW - 4
Three Days Resultant Wind		NE - 4	

Wind speed: knots.

Table 34. Wind Data in Houston on 8-23, 25, 28, 11-29, 12-1, 4, 1972, and 2-5, 6, 15, 1973.

TIME	DATE								
	8-23-72	8-25-72	8-28-72	11-29-72	12-1-72	12-4-72	2-5-73	2-6-73	2-15-73
0800	SW - 4	S - 7	N -	NE - 12	S - 4	NNW - 11	SSW - 5	N -	NNE - 11
0900	W - 4	S - 6	N - 7	NE - 12	SSW - 5	NNW - 11	S - 7	ESE - 4	NNE - 10
1000	WSW - 5	SSW - 9	NNW - 8	NE - 12	SSE - 8	N - 10	SSW - 10	SE - 5	N - 8
1100	SW - 10	SSW - 10	NNW - 5	ENE - 12	S - 8	N - 9	SSW - 14	SE - 4	N - 6
1200	NW - 5	S - 5	NNE - 6	NE - 12	S - 10	N - 11	SSW - 14	SSE - 4	NW - 12
1300	NNE - 9	ESE - 7	ESE - 6	ENE - 12	S - 10	NNW - 11	SSW - 8	SE - 7	N - 8
1400	ESE - 11	SSE - 5	ESE - 9	ESE - 9	SSE - 11	NNW - 11	SSE - 14	NNE - 7	N - 10
1500	SSW - 10	ENE - 6	ESE - 9	NNW - 4	S - 11	NNW - 11	SSW - 13	ESE - 14	NNW - 12
1600	SE - 8	SW - 4	E - 8	NNW - 9	SSE - 10	NNW - 8	SSW - 13	ESE - 10	NNE - 11
1700	ESE - 7	SW - 8	ESE - 10	N - 12	SE - 10	NNE - 8	S - 14	ESE - 8	N - 12
One Day Resultant Wind	S - 2	S - 5	ENE - 4	NNE - 9	SSE - 9	N - 10	SSW - 11	ESE - 5	N - 9
Three Day Resultant Wind	SE - 2			NE - 3			SSE - 2		
Total Resultant Wind	ESE - 1								

Wind speed: knots.

Table 35. Wind Data in Houston on 8-19, 25, 31, 11-29, 12-5, 9, 1972 and 2-9, 15, 1973.

TIME	DATE							
	8-19-72	8-25-72	8-31-72	11-29-72	12-5-72	12-9-72	2-9-73	2-15-73
0800	NNE - 5	S - 7	NNE - 5	NE - 12	N -	ENE - 5	NNW - 14	NNE - 11
0900	NE - 3	S - 6	NNE - 6	NE - 12	ESE - 4	NE - 4	NW - 14	NNE - 10
1000	NNE - 4	SSW - 9	NNE - 6	NE - 12	SSW - 7	S - 3	NNW - 11	N - 8
1100	S - 3	SSW - 10	E - 7	ENE - 12	S - 12	W - 5	N - 12	N - 6
1200	E - 7	S - 5	ENE - 10	NE - 12	S - 12	S - 15	N - 12	NW - 12
1300	NNE - 5	ESE - 7	SE - 6	ENE - 12	S - 14	S - 12	NNW - 10	N - 8
1400	S - 3	SSE - 5	ESE - 8	ESE - 9	S - 13	SSW - 15	N - 10	N - 10
1500	ESE - 3	ENE - 6	ESE - 12	NNW - 4	SSE - 15	WSW - 8	N - 10	NNW - 12
1600	E - 9	SW - 4	ESE - 10	NNW - 9	S - 15	SSW - 15	NNW - 13	NNE - 11
1700	ESE - 10	SW - 8	ESE - 8	N - 12	S - 15	S - 13	NNW - 15	N - 12
One Day Resultant Wind	ESE - 4	S - 5	ESE - 6	NNE - 9	S - 10	S - 8	NNW - 11	N - 9
Three Day Resultant Wind	ESE - 4			SSE - 4			N - 10	
Total Resultant Wind	NE - 2							

Wind speed: knots.

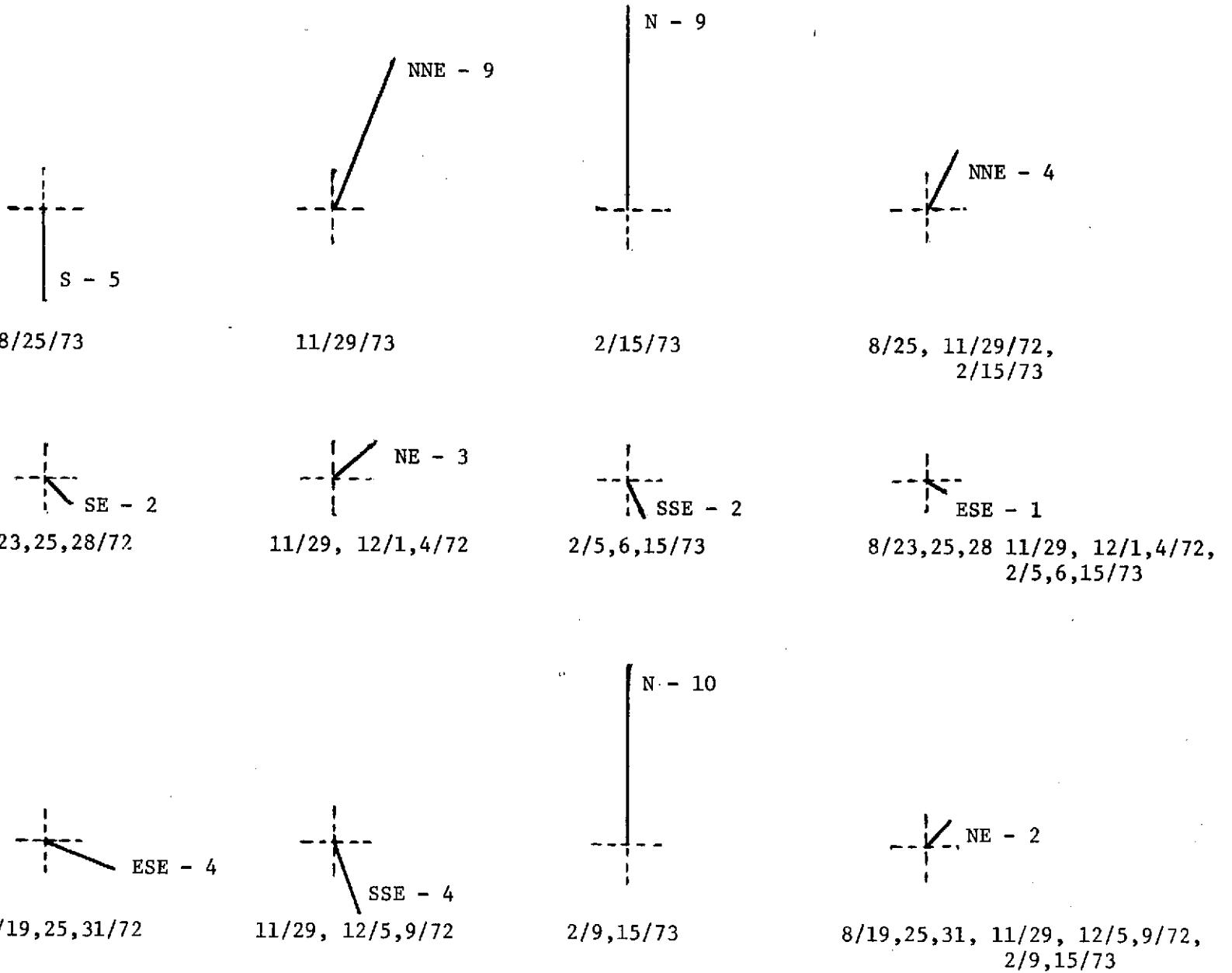


Figure 74. Summary of Resultant Wind

As to the isopleth maps of the three-day measurement, similarity between the isopleth maps of size and mass distribution of suspended particulate in August, 1972 period (Figures 24 and 26) may be due to the similar resultant winds (SE - 2, and ESE - 4). This was not true for the other time period because of different resultant winds: NE - 3 and SSE - 4 in November, 1972; SSE - 2 and N - 10 in February, 1973; and ESE - 1 and NE - 2 in the three periods combined.

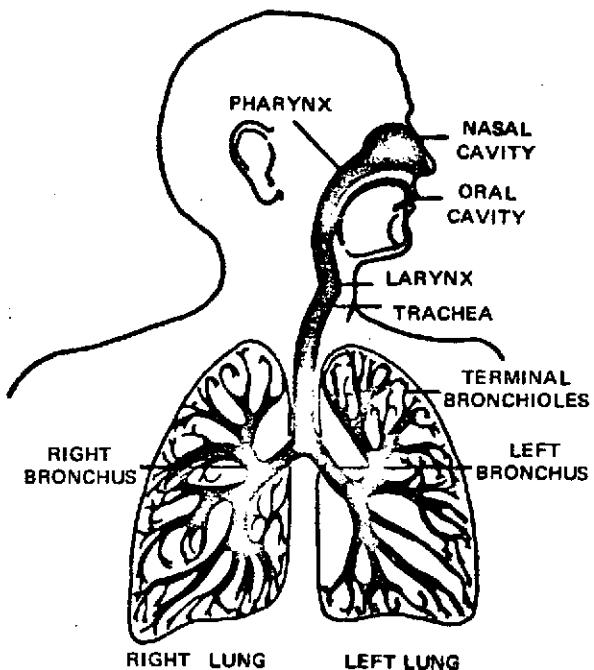
It could now be concluded that the isopleth maps of size and mass distribution of suspended particulate were essentially the same when the wind speed was 5 or less knots, and each distribution changed differently when the wind speed increased to more than 5 knots.

## V. Epidemiology of Respiratory Diseases in Houston

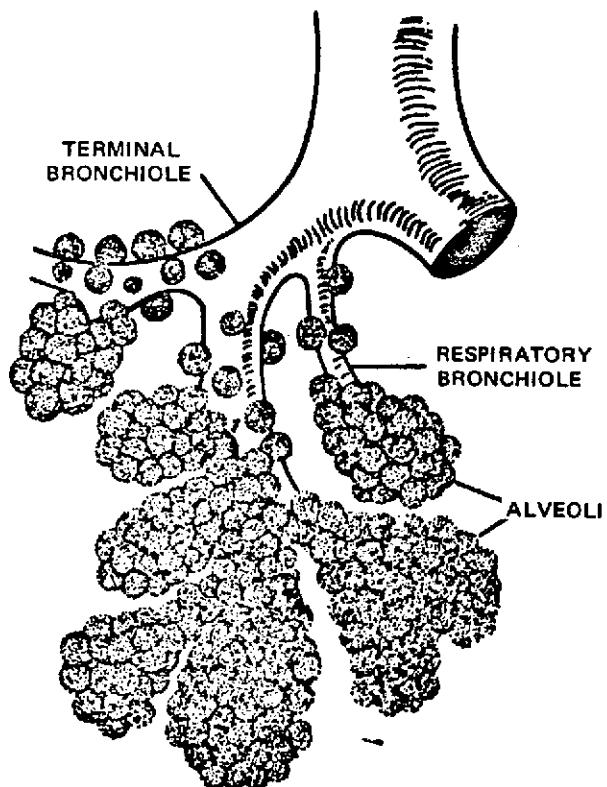
### A. The Respiratory System and Suspended Particulate Matter

The respiratory system<sup>6</sup> is usefully broken down into three main sections: (a) the nasopharyngeal structure; (b) the tracheobronchial system; and (c) the pulmonary structure. Figure 75 shows the location of these features. The nasal passages lead, via the nasopharyngeal structure and the larynx, to the trachea and the bronchi, which are made up of 23 generations of dichotomous branching tubes terminating in the alveolar (air) sacs. Figure 76 is a schematic representation in greater detail of the terminal bronchiole and pulmonary structure. The functions of respiratory system are: to supply oxygen to the circulatory system; to clear inspired air of impurities; and to warm and humidify the air.

Three mechanisms are of importance in the deposition of particulate matter in the respiratory tract: inertial impaction; gravitational settling (sedimentation); and diffusion (Brownian motion). Particles larger than 10  $\mu\text{m}$  in diameter are almost completely removed in the nose and upper respiratory passages. With progressively smaller particles, an increasing proportion of inhaled particles penetrate the nasal barrier and pass below the larynx to the trachea, bronchi, and lung parenchyma. Particles in the size range of 1 to 2  $\mu\text{m}$  penetrate deeply into the lung; approximately 50 percent are deposited on the terminal bronchioles or in the alveolar spaces. Below this size, alveolar desposition decreases because more of the smaller



**FIGURE 75** The Major Anatomical Features of the Human Respiratory System. (The diagram shows the major divisions of the human respiratory tract into nasopharyngeal, tracheobronchial, and pulmonary compartments.)



**FIGURE 76.** The Terminal Bronchial and Alveolar Structure of the Human Lung. (The diagram shows the pulmonary structure of the respiratory tract.)

particles remain suspended and are exhaled. Watson<sup>16</sup> had shown the standardized lung deposition curve in Figure 77. Thus particles of about 1  $\mu\text{m}$  in diameter and of unity density are deposited more effectively than smaller or larger particles. Penetration to the alveoli becomes zero for particles of the type considered which are larger than 12  $\mu\text{m}$  diameter. The actual mechanism of deposition is primarily dependent upon the particle size. The shape of the particle can also affect the efficiency of its deposition.

The effects of suspended particulate matter on health are the consequence of the injuries to the surfaces of the respiratory system which may be permanent or temporary. It may be confined to the surface, or it may extend beyond, sometimes producing functional or other alterations. Excess deaths and considerable increases in respiratory diseases were significantly linked to higher levels of suspended particulate matter in London, New York City, and Buffalo.<sup>6</sup>

#### B. The Respiratory Diseases in Houston

There are 158 census tracts in the Houston area<sup>17</sup> as shown in Figure 78. The individual deaths in the Houston area were tabulated according to age groups for each census tract.<sup>18</sup> The Mortality data due to asthma, bronchitis, emphysema, pneumonia, and tuberculosis was compiled from the three big volumes, "Deaths by Age Groups, Houston" in 1970, 1971 and 1972. This was a time consuming task and the three big volumes were checked through three times in order to eliminate

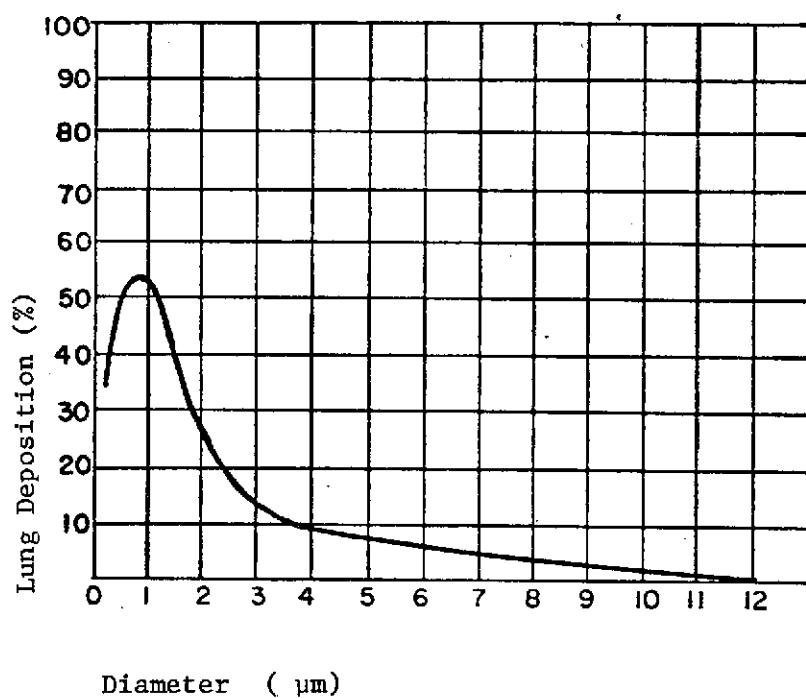


Figure 77. Standardized Lund Deposition Curve<sup>16</sup>.

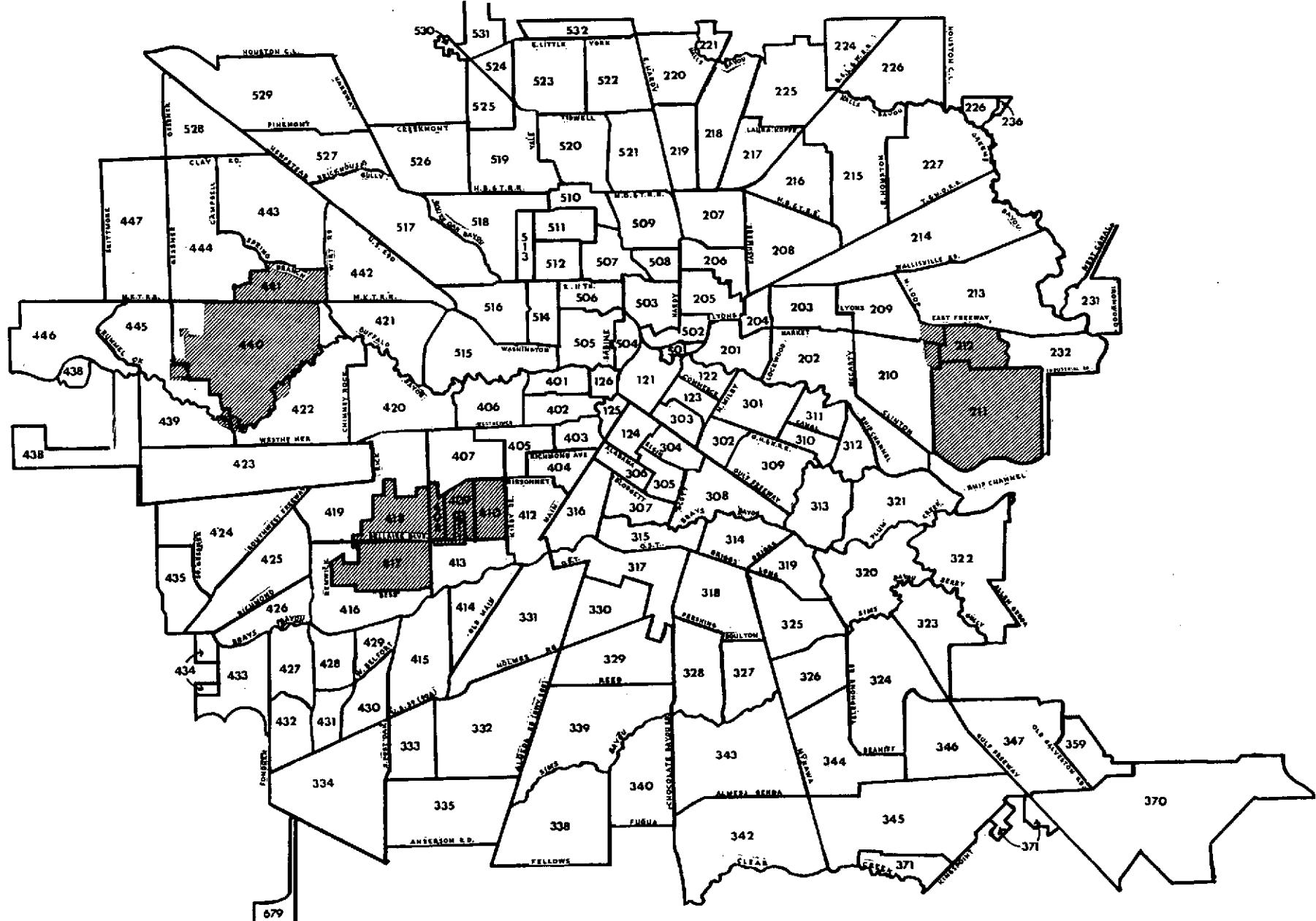


Figure 78.

## HOUSTON CENSUS TRACTS



OTHER INCORPORATED CITIES

human errors. Mortality data for pneumonia and the sum of mortality for asthma, bronchitis, and emphysema in Houston by census tract in 1970, 1971, and 1972 was shown in Table 36. Prevalence and mortality data for tuberculosis in Houston by census tract in 1970, 1971, and 1972 was shown in Table 37. Their 3-year average cases per 10,000 population for each census tract were used as input to the SYMAP computer program. The resultant conformant maps were shown in Figures 79-82.

C. The Geographical Distribution of Respiratory Diseases and the Suspended Particulate Size and Mass Distribution in Houston.

In comparing the isopleth maps of suspended particle mass concentration in Figure 2 (annual geometric mean, 1970). Figure 3 (annual geometric mean, 1971), and Figure 62 (8-19, 25, 31, 11-29, 12-5, 1972 and 2-9, 15, 1973), Figure 62 had all the heavy concentration areas that the 1970 and 1971 Figures had. Figure 62, Figure 52 (0.3-0.7  $\mu\text{m}$  size range suspended particulate distribution in 8-23, 25, 28, 11-29, 12-1, 4, 1972, and 2-5, 6, 15, 1973), and Figure 83 (Houston census tracts by socio-economic status) were used in a comparison with the isopleth maps of respiratory diseases in Figures 79-82.

The downtown area had the highest mass concentration ( $96-110 \mu\text{g}/\text{m}^3$ ) and the largest number of particles ( $18 \times 10^6 - 35 \times 10^6 \#/ \text{m}^3$ ), and the area north of the Houston Ship Channel had the second highest mass concentration ( $82-96 \mu\text{g}/\text{m}^3$ ) and the largest number of particles. The downtown area and the area north of the Houston Ship Channel have the low and medium low social economic status respectively. The downtown area

Table 36 . Mortality Data for Pneumonia and the Sum of Mortality for  
Asthma, Bronchitis, and Emphysema in Houston by Census  
Tract in 1970, 1971, and 1972.

Census Tract	Population	Asthma, Bronchitis, and Emphysema				Pneumonia			
		1970	1971	1972	Case/10,000 3-yr. Average	1970	1971	1972	Case/10,000 3-yr. Average
121	3,719	3	1	1	4.5	0	2	1	2.7
122	4,627	2	0	0	1.4	1	0	2	2.2
123	2,042	0	0	0	0.0	1	0	1	3.3
124	4,822	4	1	0	3.5	4	3	2	6.2
125	1,391	1	0	0	2.4	0	3	0	7.2
126	7,448	4	2	0	2.7	2	6	3	4.9
201	10,834	1	2	2	1.5	2	4	6	3.7
202	6,567	4	2	1	3.6	2	1	1	2.0
203	13,497	3	4	2	2.2	4	1	5	2.5
204	4,167	1	0	1	1.6	0	0	0	0.0
205	16,235	1	2	3	1.2	6	5	2	2.7
206	9,231	2	0	1	1.1	4	2	3	3.3
207	10,159	2	3	1	2.0	0	2	2	1.3
208	14,711	4	0	0	0.9	2	0	1	0.7
209	875	0	0	1	3.8	0	0	0	0.0
210	11,981	2	1	0	0.8	0	3	0	0.8

Census Tract	Population	Asthma, Bronchitis, and Emphysema				Pneumonia			
		1970	1971	1972	Case/10,000 3-yr. Average	1970	1971	1972	Case/10,000 3-yr. Average
211	10,516	2	0	0	0.6	0	1	1	0.6
212	9,563	0	1	2	1.1	6	2	1	3.1
213	5,311	0	0	1	0.6	1	0	0	0.6
214	3,586	3	0	1	3.7	2	4	0	5.6
215	16,983	1	5	1	1.4	4	2	3	1.8
216	6,796	0	0	0	0.0	2	2	1	2.5
217	11,807	0	1	2	0.8	5	4	3	3.4
218	11,190	1	3	0	1.2	4	3	1	2.4
219	5,964	1	2	1	2.2	1	0	3	2.2
220	6,904	5	2	3	4.8	1	0	2	1.5
221	2,478	0	0	1	1.3	0	0	0	0.0
224	14,239	2	2	2	1.4	0	0	0	0.0
225	15,844	1	1	2	0.8	2	0	6	1.7
226	3,014	0	0	0	0.0	1	1	1	3.3
227	5,818	0	0	1	0.6	0	0	0	0.0
231	6,965	0	0	0	0.0	0	1	2	1.4

Census Tract	Population	Asthma, Bronchitis, and Emphysema				Pneumonia			
		1970	1971	1972	Case/10,000 3-yr. Average	1970	1971	1972	Case/10,000 3-yr. Average
232	5,750	1	0	1	1.2	0	2	0	1.2
236	1,747	0	0	0	0.0	0	0	0	0.0
301	10,545	3	1	1	1.6	5	2	2	2.9
302	5,813	4	2	2	4.6	0	1	2	1.7
303	3,581	1	1	1	2.8	4	3	0	6.5
304	14,304	3	2	0	1.2	3	2	3	1.9
305	11,318	2	1	1	1.2	4	6	4	4.1
306	7,634	1	0	1	0.9	1	1	2	1.8
307	12,519	2	3	3	2.1	4	4	4	3.2
308	7,024	1	1	2	1.9	1	2	0	1.4
309	9,723	7	0	2	3.1	2	2	2	2.1
310	6,322	2	1	1	2.1	1	0	1	1.1
311	9,396	8	1	0	3.2	0	2	2	1.4
312	7,923	2	2	2	2.5	2	2	0	1.7
313	9,801	3	4	2	3.1	1	1	2	1.4
314	7,621	1	0	1	0.9	0	1	2	1.3

Census Tract	Population	Asthma, Bronchitis, and Emphysema				Pneumonia			
		1970	1971	1972	Case/10,000 3-yr. Average	1970	1971	1972	Case/10,000 3-yr. Average
315	7,663	1	2	0	1.3	4	2	1	3.1
316	5,544	0	1	1	1.2	1	1	1	1.8
317	15,484	1	2	1	0.9	3	6	4	2.8
318	19,071	4	3	1	1.4	4	1	1	1.1
319	5,786	1	2	1	2.3	1	0	1	1.2
320	15,447	5	5	4	3.0	2	4	5	2.4
321	11,704	5	4	3	3.4	1	0	4	1.4
322	11,760	0	0	5	1.4	0	0	0	0.0
323	8,408	1	3	2	2.4	0	0	1	0.4
324	11,900	3	2	1	1.7	2	1	1	1.1
325	9,213	1	4	7	4.3	1	1	2	1.5
326	7,729	2	1	2	2.2	0	0	0	0.0
327	10,399	1	0	0	0.3	1	1	0	0.6
328	16,144	2	1	3	1.2	1	4	4	1.9
329	10,526	4	1	0	1.6	4	3	2	2.9
330	5,413	2	1	0	1.8	1	1	1	1.9

Census Tract	Population	Asthma, Bronchitis, and Emphysema				Pneumonia			
		1970	1971	1972	Case/10,000 3-yr. Average	1970	1971	1972	Case/10,000 3-yr. Average
331	1,029	0	0	0	0.0	1	0	2	9.7
332	6,479	0	0	0	0.0	0	0	0	0.0
333	2,742	0	0	0	0.0	1	0	0	1.2
334	5,559	0	1	1	1.2	0	0	0	0.0
335	12,921	2	2	2	1.5	1	1	1	0.8
338	2,641	0	0	0	0.0	0	1	0	1.3
339	10,017	3	0	0	1.0	1	0	3	1.3
340	7,451	1	0	2	1.3	2	0	2	1.8
342	1,080	0	0	0	0.0	1	1	0	6.2
343	7,187	0	0	1	0.5	0	0	1	0.5
344	1,706	2	0	0	3.9	0	0	0	0.0
345	6,601	0	0	0	0.0	0	0	0	0.0
346	1,970	1	1	0	3.4	1	0	0	1.7
347	18,217	1	1	0	0.4	0	0	0	0.0
359	4,861	0	0	0	0.0	0	0	0	0.0
370	746	0	0	0	0.0	0	1	0	4.5

Census Tract	Population	Asthma, Bronchitis, and Emphysema				Pneumonia			
		1970	1971	1972	Case/10,000 3-yr. Average	1970	1971	1972	Case/10,000 3-yr. Average
371	9,490	0	0	0	0.0	0	0	0	0.0
401	5,963	0	0	1	0.6	1	0	1	1.1
402	11,551	5	2	4	3.2	2	1	2	1.4
403	7,058	2	4	0	2.8	2	2	1	2.4
404	6,805	0	1	2	1.5	2	4	1	3.4
405	9,340	6	2	3	3.9	2	1	3	2.1
406	5,978	1	3	0	2.2	0	0	4	2.2
407	10,349	2	1	2	1.6	0	1	0	0.3
408	3,381	1	0	0	1.0	4	0	2	5.9
409	3,963	2	2	2	5.1	2	0	0	1.7
410	5,973	1	2	0	1.7	2	0	1	1.7
411	1,466	0	1	0	2.3	0	0	1	2.3
412	9,956	3	4	0	2.3	1	4	3	2.7
413	8,654	2	2	5	3.5	0	3	1	1.5
414	8,948	2	2	1	1.9	2	0	0	0.8
415	14,834	1	5	1	1.6	1	0	0	0.2

Census Tract	Population	Asthma, Bronchitis, and Emphysema				Pneumonia			
		1970	1971	1972	Case/10,000 3-yr. Average	1970	1971	1972	Case/10,000 3-yr. Average
416	18,611	3	0	1	0.7	1	6	2	1.6
417	12,640	1	0	1	0.5	1	1	0	0.5
418	6,369	1	0	2	1.6	0	0	0	0.0
419	14,169	4	2	1	1.6	4	4	1	2.1
420	14,091	2	4	4	2.4	3	2	2	1.7
421	3,698	0	0	0	0.0	0	0	4	3.6
422	16,486	6	2	1	1.8	1	0	1	0.4
423	17,616	1	0	2	0.6	0	1	1	0.4
424	12,590	1	1	0	0.5	0	1	1	0.5
425	14,997	1	4	3	1.8	3	1	1	1.1
426	7,640	1	0	1	0.9	1	0	1	0.9
427	6,118	1	0	0	0.5	0	0	0	0.0
428	8,476	1	0	0	0.4	0	0	1	0.4
429	4,616	0	0	0	0.0	0	1	1	1.4
430	3,439	0	1	1	1.9	0	0	0	0.0
431	6,951	1	0	0	0.5	1	0	0	0.5

Census Tract	Population	Asthma, Bronchitis, and Emphysema				Pneumonia			
		1970	1971	1972	Case/10,000 3-yr. Average	1970	1971	1972	Case/10,000 3-yr. Average
432	2,345	1	0	0	1.4	0	0	0	0.0
433	6,359	0	0	0	0.0	1	0	0	0.5
434	880	0	0	0	0.0	0	0	0	0.0
435	5,937	0	1	0	0.6	0	0	0	0.0
438	7,795	1	0	0	0.4	0	0	0	0.0
439	3,866	0	1	1	1.7	0	0	0	0.0
440	16,661	5	3	3	2.2	1	1	0	0.4
441	3,847	0	0	0	0.0	0	2	0	1.7
442	12,995	1	1	2	1.0	0	1	2	0.8
443	23,189	3	2	3	1.1	3	3	3	1.3
444	18,175	1	2	0	0.6	4	6	3	2.4
445	12,873	0	1	2	0.8	1	0	1	0.5
446	21,046	0	1	0	0.2	0	2	1	0.5
447	13,844	0	0	1	0.2	1	2	1	1.0
501	126	0	0	0	0.0	0	1	0	26.5
502	3,211	3	0	1	4.2	4	3	1	8.3

Census Tract	Population	Asthma, Bronchitis, and Emphysema				Pneumonia			
		1970	1971	1972	Case/10,000 3-yr. Average	1970	1971	1972	Case/10,000 3-yr. Average
503	13,777	4	1	1	1.5	3	6	3	2.9
504	4,097	0	5	1	4.9	3	0	2	4.1
505	6,220	1	2	0	1.6	1	1	0	1.1
506	9,901	4	3	6	4.4	2	1	1	1.4
507	8,603	2	5	2	3.5	1	0	4	1.9
508	5,925	1	2	1	2.3	2	1	0	1.7
509	12,867	4	2	5	2.8	1	2	6	2.3
510	6,865	0	2	0	1.0	1	1	2	1.9
511	6,951	5	0	3	3.8	1	2	3	2.9
512	7,617	1	3	1	2.6	1	1	1	1.3
513	3,501	0	0	3	2.9	0	1	4	4.8
514	7,709	2	0	1	1.3	0	2	1	1.3
515	8,023	5	1	2	3.3	5	2	2	3.7
516	7,778	0	1	1	1.3	2	1	2	2.1
517	13,449	0	2	3	1.2	0	1	1	0.5
518	13,561	1	1	6	2.0	5	4	3	3.0

Census Tract	Population	Asthma, Bronchitis, and Emphysema				Pneumonia			
		1970	1971	1972	Case/10,000 3-yr. Average	1970	1971	1972	Case/10,000 3-yr. Average
519	13,602	3	2	6	2.7	3	0	1	1.0
520	12,975	7	1	2	2.7	3	2	6	2.8
521	10,253	2	5	1	2.6	4	3	1	2.6
522	11,967	0	3	1	1.1	0	2	1	0.8
523	11,908	2	4	1	2.0	1	2	0	0.8
524	2,121	1	0	1	3.1	0	0	3	4.7
525	10,659	2	0	0	0.6	1	0	1	0.6
526	16,491	1	2	1	0.8	3	2	5	2.2
527	9,680	1	0	0	0.3	1	0	0	0.3
528	2,033	0	1	0	1.6	1	1	1	4.9
529	4,513	0	0	0	0.0	0	0	0	0.0
530	8,929	1	0	2	1.1	3	2	1	2.2
531	13,744	3	4	3	2.4	1	2	1	1.0
532	12,736	0	1	1	0.5	0	0	0	0.0

Table 37 . Prevalence and Mortality Data for Tuberculosis in Houston by Census Tract in 1970, 1971, and 1972.

Census Tract	Population	Prevalence				Mortality			
		1970	1971	1972	Case/10,000 3-yr. Average	1970	1971	1972	Case/10,000 3-yr. Average
121	3,719	16	17	29	55.6	2	4	1	6.3
122	4,627	11	3	1	10.8	0	0	2	1.4
123	2,042	3	4	7	22.9	1	0	0	1.6
124	4,822	6	8	2	11.1	0	1	0	0.7
125	1,391	4	2	0	14.4	0	0	0	0.0
126	7,448	10	10	8	12.5	2	2	0	1.8
201	10,834	17	10	9	11.1	0	2	0	0.6
202	6,567	2	4	5	5.6	1	0	0	0.5
203	13,497	5	5	10	4.9	0	2	0	0.5
204	4,167	5	3	1	7.2	0	0	0	0.0
205	16,235	13	12	7	6.6	3	2	1	1.2
206	9,231	12	6	9	9.8	0	1	1	0.7
207	10,159	5	4	4	4.3	0	1	0	0.3
208	14,711	8	10	7	5.7	0	0	2	0.5
209	875	0	1	0	3.8	0	0	0	0.0
210	11,981	4	9	7	5.6	0	0	2	0.6
211	10,516	1	7	2	3.2	0	0	0	0.0

Census Tract	Population	Prevalence				Mortality			
		1970	1971	1972	Case/10,000 3-yr. Average	1970	1971	1972	Case/10,000 3-yr. Average
212	9,563	2	0	1	1.1	0	0	0	0.0
213	5,311	0	2	0	1.3	0	0	0	0.0
214	3,586	2	1	1	3.7	0	0	0	0.0
215	16,983	9	4	2	2.9	2	0	0	0.4
216	6,796	4	1	3	3.9	0	0	0	0.0
217	11,807	12	2	7	5.9	1	0	1	0.6
218	11,190	6	7	3	4.8	1	0	1	0.6
219	5,964	5	4	2	6.2	1	1	0	1.1
220	6,904	5	2	4	5.3	1	0	1	1.0
221	2,478	0	0	1	1.4	0	0	0	0.0
224	14,239	8	6	3	4.0	0	0	0	0.0
225	15,844	1	4	3	1.7	0	1	0	0.2
226	3,014	0	1	0	1.1	0	0	0	0.0
227	5,818	0	2	1	1.7	0	0	0	0.0
231	6,965	2	0	1	1.4	0	0	0	0.0
232	5,750	2	2	3	4.1	0	0	0	0.0
236	1,747	0	0	0	0.0	0	0	0	0.0

Census Tract	Population	Prevalence				Mortality			
		1970	1971	1972	Case/10,000 3-yr. Average	1970	1971	1972	Case/10,000 3-yr. Average
301	10,545	19	15	6	12.6	1	1	1	1.0
302	5,813	10	4	3	9.7	0	0	0	0.0
303	3,581	6	3	6	14.0	2	0	0	1.9
304	14,304	20	8	9	8.6	0	3	3	1.4
305	11,318	2	9	9	5.9	1	0	0	0.3
306	7,634	5	12	6	10.0	0	0	0	0.0
307	12,519	3	7	4	3.7	0	0	1	0.3
308	7,024	2	2	1	2.4	1	0	0	0.5
309	9,723	3	2	2	2.4	0	1	0	0.3
310	6,322	2	3	8	6.9	0	0	0	0.0
311	9,396	3	9	7	6.7	0	0	1	0.4
312	7,923	6	5	7	7.6	0	0	0	0.0
313	9,801	3	5	5	4.4	1	1	0	0.7
314	7,621	4	8	4	7.0	0	0	0	0.0
315	7,663	5	0	1	2.6	2	1	0	1.3
316	5,544	6	1	2	5.4	0	0	0	0.0
317	15,484	4	4	6	3.0	1	0	0	0.2

Census Tract	Population	Prevalence				Mortality			
		1970	1971	1972	Case/10,000 3-yr. Average	1970	1971	1972	Case/10,000 3-yr. Average
318	19,071	7	9	7	4.0	1	0	0	0.2
319	5,786	0	1	1	1.2	0	0	0	0.0
320	15,447	4	1	3	1.7	0	0	1	0.2
321	11,704	9	7	4	5.7	0	0	0	0.0
322	11,760	2	2	1	1.4	0	0	0	0.0
323	8,408	0	3	0	1.2	0	0	0	0.0
324	11,900	2	1	1	1.1	0	0	0	0.0
325	9,213	0	1	1	0.7	0	0	0	0.0
326	7,729	0	0	0	0.0	0	0	0	0.0
327	10,399	2	5	5	3.9	0	0	0	0.0
328	16,144	11	2	8	4.3	0	0	1	0.2
329	10,526	9	5	10	7.6	0	0	1	0.3
330	5,413	1	7	1	5.5	0	0	0	0.0
331	1,029	1	1	0	6.5	0	0	0	0.0
332	6,479	0	2	2	2.1	0	1	0	0.5
333	2,742	0	0	0	0.0	0	0	0	0.0
334	5,559	1	1	0	1.2	0	0	0	0.0

Census Tract	Population	Prevalence				Mortality			
		1970	1971	1972	Case/10,000 3-yr. Average	1970	1971	1972	Case/10,000 3-yr. Average
335	12,921	0	1	1	0.5	0	1	0	0.3
338	2,641	2	1	1	5.1	0	0	0	0.0
339	10,017	6	3	12	7.0	0	0	0	0.0
340	7,451	0	0	3	1.3	0	0	0	0.0
342	1,080	0	0	0	0.0	0	0	0	0.0
343	7,187	2	2	6	4.6	1	1	0	0.9
344	1,706	1	1	0	3.9	0	0	0	0.0
345	6,601	0	0	2	1.0	0	0	1	0.5
346	1,970	0	1	1	3.4	0	0	0	0.0
347	18,217	0	2	1	0.6	0	0	0	0.0
359	4,861	0	0	0	0.0	0	0	0	0.0
370	746	0	0	0	0.0	0	0	0	0.0
371	9,490	0	0	0	0.0	0	0	0	0.0
401	5,963	8	4	9	11.7	1	0	1	1.1
402	11,551	7	4	7	5.2	1	0	1	0.6
403	7,058	0	0	1	0.5	0	0	0	0.0
404	6,805	0	4	2	2.9	0	0	0	0.0

Census Tract	Population	Prevalence				Mortality			
		1970	1971	1972	Case/10,000 3-yr. Average	1970	1971	1972	Case/10,000 3-yr. Average
405	9,340	5	5	2	4.3	0	0	0	0.0
406	5,978	0	0	0	0.0	0	0	0	0.0
407	10,349	2	2	1	1.6	0	0	0	0.0
408	3,381	0	0	1	1.0	0	0	0	0.0
409	3,963	0	0	0	0.0	0	0	0	0.0
410	5,973	0	1	0	0.6	0	1	0	0.6
411	1,466	0	0	1	2.3	0	0	0	0.0
412	9,956	3	1	3	2.3	0	0	0	0.0
413	8,654	1	0	1	0.8	0	0	0	0.0
414	8,948	0	4	0	1.5	0	0	1	0.4
415	14,834	1	1	1	0.7	1	1	0	0.5
416	18,611	0	1	1	0.4	0	0	0	0.0
417	12,640	0	0	1	0.3	0	0	0	0.0
418	6,369	2	0	1	1.6	0	0	0	0.0
419	14,169	3	1	1	1.2	0	0	0	0.0
420	14,091	1	1	1	0.7	0	0	0	0.0
421	3,698	0	0	0	0.0	0	0	0	0.0

Census Tract	Population	Prevalence				Mortality			
		1970	1971	1972	Case/10,000 3-yr. Average	1970	1971	1972	Case/10,000 3-yr. Average
422	16,486	0	1	5	1.2	0	0	0	0.0
423	17,616	0	1	0	0.2	0	0	0	0.0
424	12,590	1	1	0	0.5	0	0	0	0.0
425	14,997	1	1	0	0.5	0	1	0	0.2
426	7,640	1	0	0	0.4	1	0	0	0.4
427	6,118	0	1	0	0.5	0	0	0	0.0
428	8,476	0	0	0	0.0	0	0	0	0.0
429	4,616	0	0	0	0.0	0	0	0	0.0
430	3,439	1	0	0	1.0	0	0	0	0.0
431	6,951	0	0	1	0.5	0	0	0	0.0
432	2,345	0	0	0	0.0	0	0	0	0.0
433	6,359	0	0	1	0.5	0	0	0	0.0
434	880	1	0	0	3.8	0	0	0	0.0
435	5,937	0	0	0	0.0	0	0	0	0.0
438	7,795	0	0	0	0.0	0	0	0	0.0
439	3,866	1	1	1	2.6	0	0	1	0.9
440	16,661	2	0	0	0.4	0	0	0	0.0

Census Tract	Population	Prevalence				Mortality			
		1970	1971	1972	Case/10,000 3-yr. Average	1970	1971	1972	Case/10,000 3-yr. Average
441	3,847	1	1	0	1.7	0	0	0	0.0
442	12,995	1	1	1	0.8	0	0	0	0.0
443	23,189	2	0	4	0.9	0	0	0	0.0
444	18,175	3	2	0	0.9	1	0	0	0.2
445	12,873	1	0	1	0.5	0	0	0	0.0
446	21,046	0	2	2	0.6	0	0	0	0.0
447	13,844	2	0	2	1.0	0	0	0	0.0
501	126	0	0	0	0.0	0	0	0	0.0
502	3,211	6	6	2	14.5	0	1	1	2.1
503	13,777	7	15	19	9.9	1	1	3	1.2
504	4,097	5	12	4	17.1	1	1	0	1.6
505	6,220	10	10	11	16.6	0	0	1	0.5
506	9,901	9	8	2	6.4	1	1	1	1.0
507	8,603	6	6	1	5.0	0	1	0	0.4
508	5,925	1	5	5	6.2	0	0	0	0.0
509	12,867	12	7	3	5.7	0	0	0	0.0
510	6,865	2	5	7	6.8	0	1	1	1.0

Census Tract	Population	Prevalence				Mortality			
		1970	1971	1972	Case/10,000 3-yr. Average	1970	1971	1972	Case/10,000 3-yr. Average
511	6,951	2	9	2	6.2	0	0	0	0.0
512	7,617	1	3	2	2.6	1	1	0	0.9
513	3,501	6	1	1	7.6	0	0	0	0.0
514	7,709	4	8	0	5.2	0	1	0	0.4
515	8,023	6	6	5	7.1	0	0	0	0.0
516	7,778	7	1	5	5.6	0	0	0	0.0
517	13,449	1	5	2	2.0	0	0	0	0.0
518	13,561	5	7	8	4.9	1	0	1	0.5
519	13,602	3	9	5	4.2	0	0	0	0.0
520	12,975	6	4	3	3.3	0	1	0	0.3
521	10,253	2	8	4	4.6	0	0	0	0.0
522	11,967	8	1	5	3.9	1	0	0	0.3
523	11,908	1	2	3	1.7	0	0	0	0.0
524	2,121	0	2	0	3.1	0	0	0	0.0
525	10,659	4	2	4	3.1	0	0	0	0.0
526	16,491	2	0	7	1.8	1	0	0	0.2
527	9,680	0	1	1	0.7	0	0	0	0.0

Census Tract	Population	Prevalence				Mortality			
		1970	1971	1972	Case/10,000 3-yr. Average	1970	1971	1972	Case/10,000 3-yr. Average
528	2,033	0	0	0	0.0	0	0	0	0.0
529	4,513	1	1	0	1.5	0	0	0	0.0
530	8,929	0	0	3	1.1	0	0	0	0.0
531	13,744	0	0	4	1.0	0	0	0	0.0
532	12,736	0	0	0	0.0	0	0	0	0.0

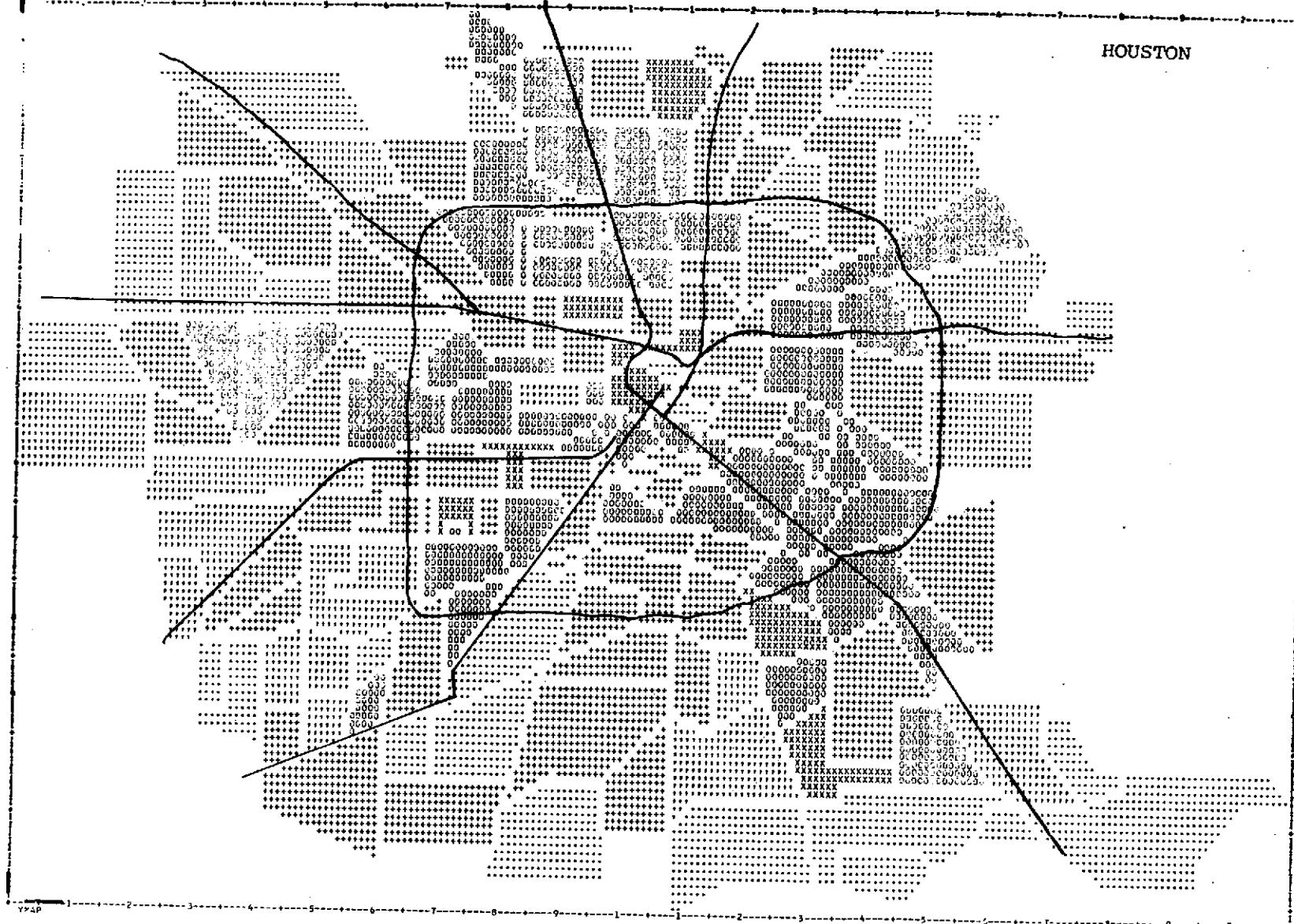


Figure 79. Sum of Mortality for Asthma, Bronchitis, and Emphysema in Houston by Census Tract in 1970, 1971, 1972.  
3-Year Average Case/10,000

Level	1	2	3	4	5
Maximum	0.26	0.77	1.81	3.87	8.00
Minimum	0.00	0.26	0.77	1.81	3.87
Symbol	.....	, , ,	+ + +	000000	xxxxxx
Frequency	25	20	58	47	10

## HOUSTON

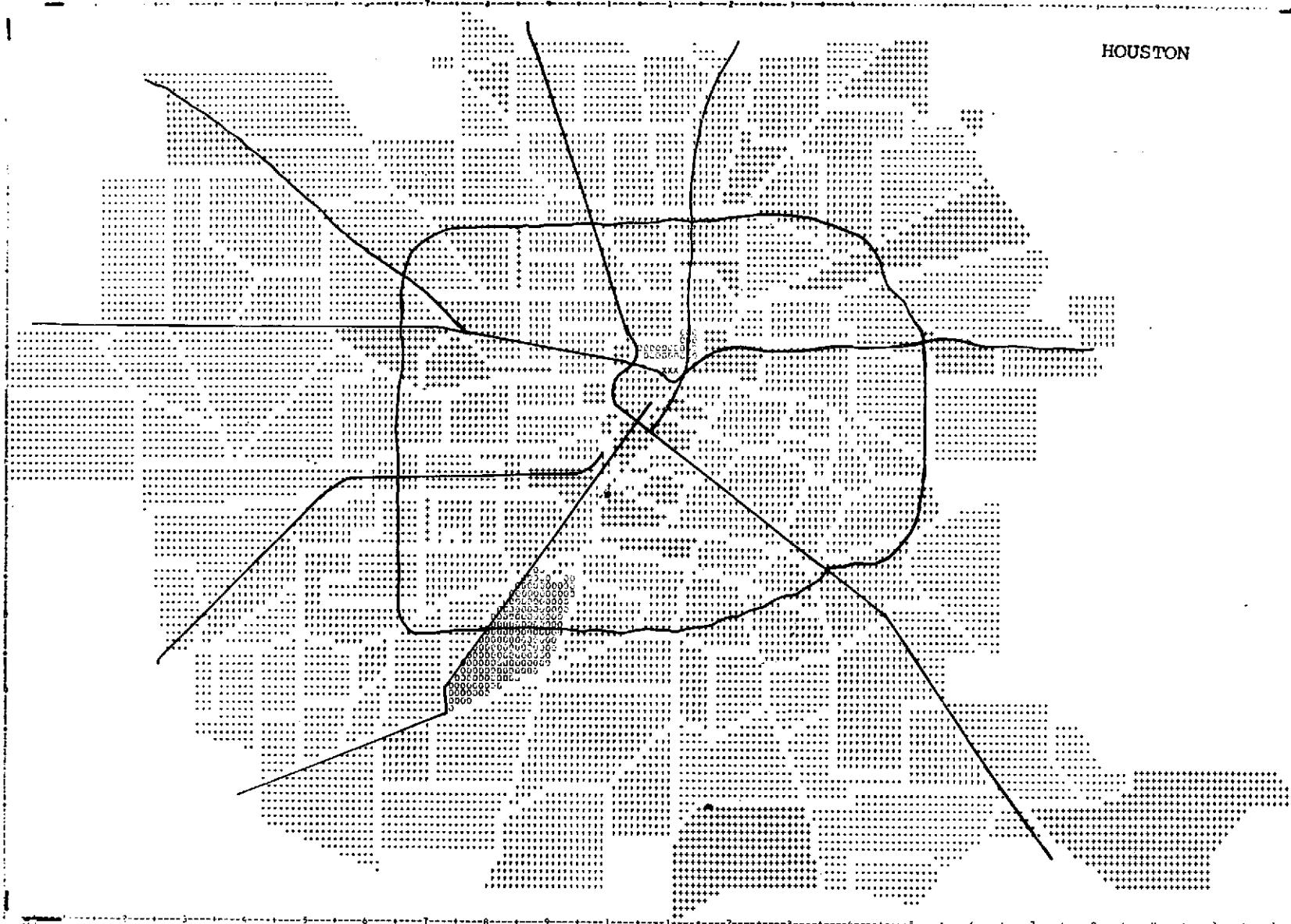


Figure 80. Mortality for Pneumonia in Houston  
by Census Tract in 1970, 1971, and  
1972.  
3-Year Average, Case/10,000

Level	1	2	3	4	5
Maximum	1.03	3.10	7.23	15.48	32.00
Minimum	0.00	1.03	3.10	7.23	15.48
Symbol	.....	, , , , ,	+ + +	000000	xxxxxx
Frequency	57	75	25	2	1

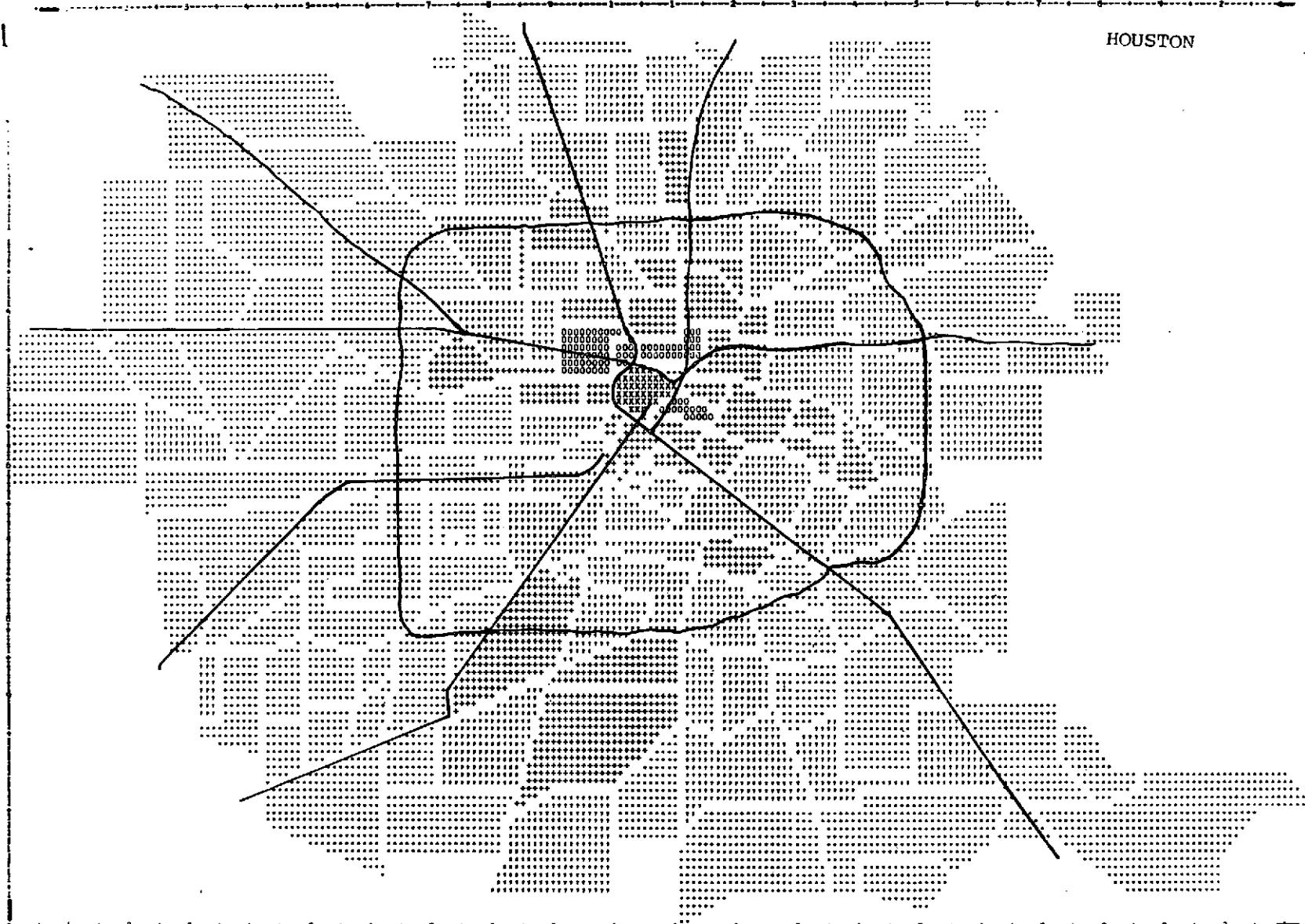


Figure 81. Prevalence for Tuberculosis in Houston by Census Tract in 1970, 1971, and 1972.  
3-Year Average, Case/10,000

Level	1	2	3	4	5
Maximum	2.06	6.19	14.45	30.97	64.00
Minimum	0.00	2.06	6.19	14.45	30.97
Symbol	.....	, , , ,	+++	000000	xxxxxx
Frequency	74	52	29	4	1

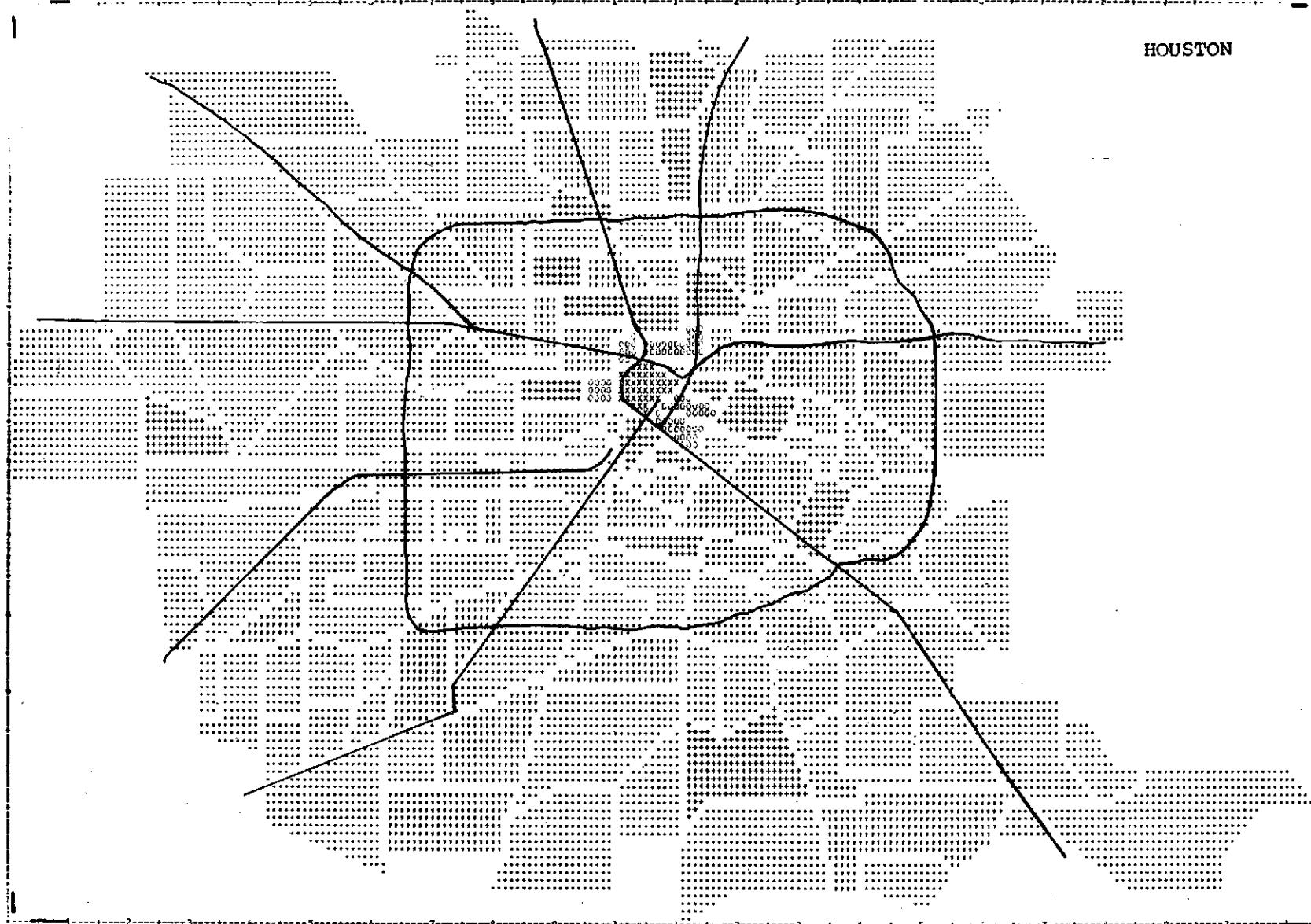


Figure 82. Mortality for Tuberculosis in Houston by Census Tract in 1970, 1971, 1972.  
3-Year Average, Case/10,000

Level	1	2	3	4	5
Maximum	0.21	0.62	1.45	3.10	6.40
Minimum	0.00	0.21	0.62	1.45	3.10
Symbol	.....	,, , ,	++ +	000000	xxxxxx
Frequency	108	29	17	5	1

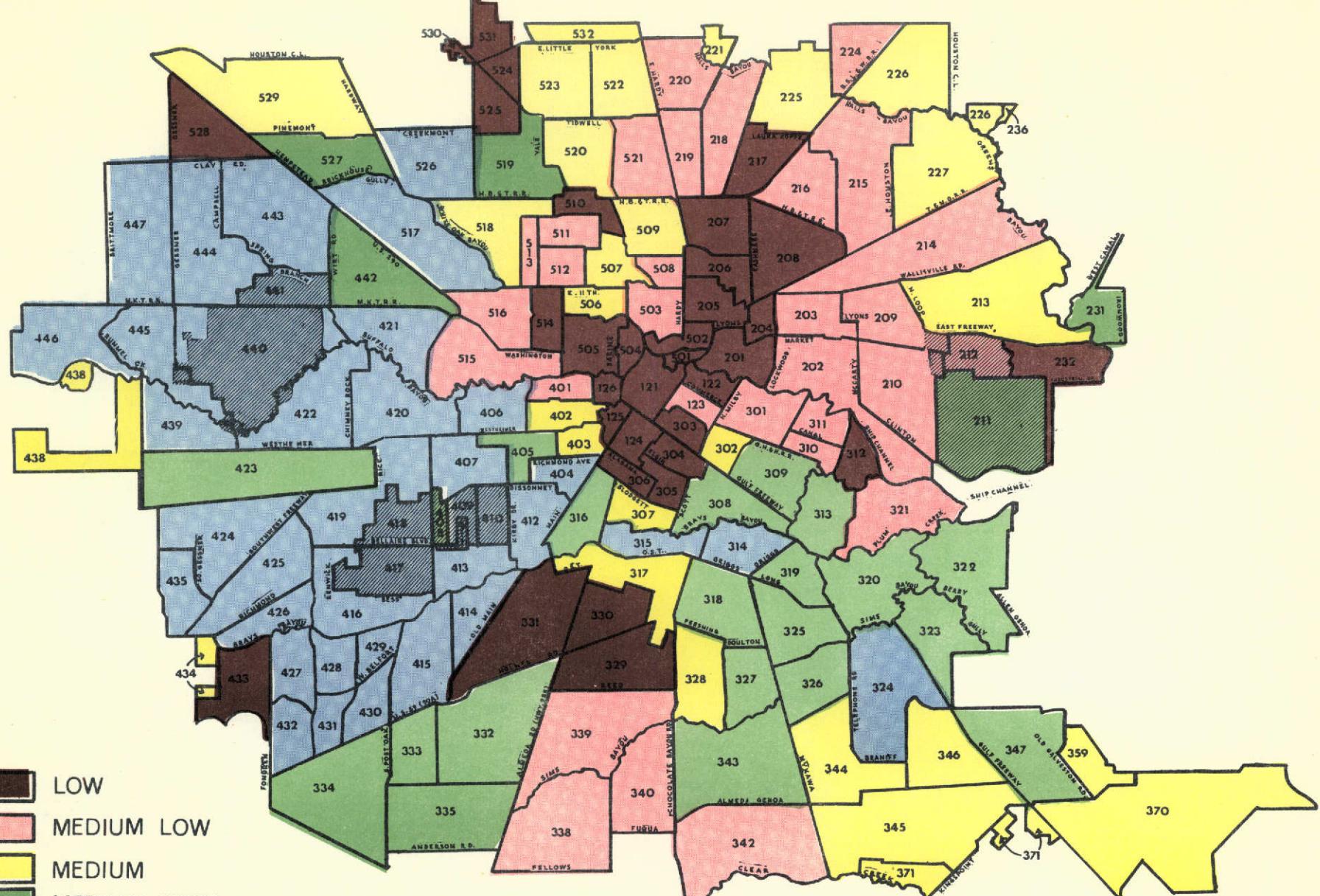


Figure 83 **HOUSTON**  
CENSUS TRACTS BY SOCIAL ECONOMIC STATUS  
**OTHER INCORPORATED CITIES**

had the highest mortality for asthma, bronchitis, and emphysema combined (3.87 - 8.00 cases /10,000), while the area north of the Houston Ship Channel had the Second highest mortality (1.81 - 3.87 cases/10,000). Two other areas (census tracts 325 and 344) having the highest mortality had the second largest number of particles ( $10 \times 10^6$  -  $18 \times 10^6$  #/ $m^3$ ) and the second lowest particle mass concentration (54-68  $\mu g/m^3$ ). Most other areas having, the second highest mortality for asthma, bronchitis, and emphysema combined had the second largest number of particles and only 50% of these areas had the second highest mass concentration. Census tract 440 in west Houston and census tracts 531,524,523,519,520,521, and 219 in north Houston all had the second highest mortality but a low level of suspended particle size and mass concentration which may be due to lack of sampling stations in those areas. From the summary in Table 38, the mortality of asthma, bronchitis, and emphysema visually associated quite well with suspended particulate size and mass distribution, and better with size distribution than with mass distribution. The socioeconomic status does not play a decisive role here since the highest mortality areas consist of low, medium, medium high socioeconomic status and the areas having second highest mortality for asthma, bronchitis, and emphysema combined involve every kind of socioeconomic status.

In the case of pneumonia, the downtown area had the highest mortality rate (16 - 32 cases/10,000), and the area north of the Houston Ship Cannel had the third highest mortality rate ( 3-7 cases/10,000). Census tract 331 with

Table 38. The Correlation of Number and Weight of Suspended Particulate Matter, Socio-economic Status to the Sum of Mortality for Asthma, Bronchitis, and Emphysema in Houston 1970, 1971 and 1972.

Area	Downtown Area	Area North of Houston Ship Channel	Census Tract 325	Census Tract 344	Other Areas
Mortality	Highest	2nd Highest	Highest	Highest	2nd Highest
Number of Suspended Particulate Matter	Largest	Largest	2nd Largest	2nd Largest	All 2nd Largest
Weight of Suspended Particulate Matter	Highest	2nd Highest	2nd Lowest	2nd Lowest	50% 2nd Highest
Socio-economic Status	Low	Medium Low	Medium High	Medium	All status

the low socioeconomic status had the second highest mortality rate (7 - 16 cases/10,000), the third in number of suspended particulate matter ( $6 \times 10^6$  -  $10 \times 10^6$  #/ $m^3$ ).

The condition in census tracts 342,515,370,421 also included in Table 39. The pneumonia mortality in Houston was mostly linked to a lower socioeconomic status, a higher level of suspended particulate size and mass concentration with more emphasis on a lower socioeconomic status.

In the case of tuberculosis prevalence, the downtown area had the highest prevalence rate (30-60 cases/10,000), and the area north of the Houston Ship Channel had the second lowest prevalence rate (2-6 cases/10,000). Other areas with third prevalence rate (6-15 cases/10,000) had the second to third level of suspended particulate size and mass concentration, and all these areas had either low or medium low socioeconomic status with only census tract 314 as an exception. They are summarized in Table 40. This confirms other findings that a high rate of tuberculosis prevalence was observed mostly in lower socioeconomic status area. Here the high level of suspended particulate pollution might aggravate the situation as shown in the downtown area.

In the case of tuberculosis mortality, the downtown area had the highest mortality rate (3-6 cases/10,000) and the area north of the Houston Ship Channel had the lowest mortality rate (0 - 0.2 case/10,000). Census tracts 301, 313, 343, and 439 had the third highest mortality rate (0.6 - 1.5 cases/10,000). Census tract 301 with a medium low socioeconomic status had the third highest level of particle

Table 39. The Correlation of Number and Weight of Suspended Particulate Matter and Socioeconomic Status to the Mortality for Pneumonia in Houston in 1970, 1971, and 1972.

Area	Downtown Area	Census Tract 331	Area North of Houston Ship Channel	Census Tract 342	Census Tract 515	Census Tract 370	Census Tract 421
Mortality	Highest	2nd Highest	3rd Highest	3rd Highest	3rd Highest	3rd Highest	3rd Highest
Number of Suspended Particulate Matter	Largest	3rd Largest	Largest	3rd Largest	2nd Largest	3rd Largest	2nd Largest
Weight of Suspended Particulate Matter	Highest	2nd Highest	2nd Highest	4th Highest	3rd Highest	4th Highest	3rd Highest
Socio-economic Status	Low	Low	Medium Low	Medium Low	Medium Low	Medium	High

Table 40. The correlation of Number and Weight of Suspended Particulate Matter, and Socioeconomic Status to the Tuberculosis Prevalence in Houston in 1970, 1971 and 1972.

Area	Downtown Area	Area North of Houston Ship Channel	Census Tracts 331, 312	Census Tract 329	Census Tracts 515	Census Tracts 301, 310, 311	Census Tract 339	Census Tract 314
Prevalence	Highest	2nd Lowest	3rd Highest	3rd Highest	3rd Highest	3rd Highest	3rd Highest	3rd Highest
Number of Suspended Particulate Matter	Largest	Largest	2nd Largest	3rd Largest	2nd Largest	2nd Largest	3rd Largest	2nd Largest
Weight of Suspended Particulate Matter	Highest	2nd Highest	2nd Highest	2nd Highest	3rd Highest	2nd Highest	2nd Highest	2nd Highest
Socio-economic Status	Low	Medium Low	Low	Low	Medium Low	Medium Low	Medium Low	High

number ( $6 \times 10^6 - 10 \times 10^6 \text{#/m}^3$ ) and second lowest level of particle mass concentration ( $54-68 \mu\text{g/m}^3$ ). Census tract 313 with a medium high socioeconomic status had the third highest particle number and the second highest particle mass concentration ( $82-96 \mu\text{g/m}^3$ ). Census tract 343 with a medium high socioeconomic status had the third largest particle number and the second lowest level of particle mass concentration ( $54-68 \mu\text{g/m}^3$ ).\* These are summarized in Table 41. It may be concluded from this data that the tuberculosis mortality did not relate to the socioeconomic status, the level of particle number and mass concentration in a meaningful way. But it should be mentioned that the downtown and surrounding areas had a high tuberculosis mortality, 1.5 - 3.1 cases/10,000 respectively. The population of these areas consists of many elderly people. The high level of particle number and mass concentration in these areas could tend to raise the tuberculosis mortality of this age group.

\* Census tract 439 with a high socioeconomic status had the third highest level of particle number and mass concentration ( $68.82 \mu\text{g/m}^3$ ).

Table 41. The Correlation of Number and Weight of Suspended Particulate Matter, and Socioeconomic Status to the Tuberculosis Mortality in Houston in 1970, 1971 and 1972.

Area	Downtown Area	Area North of Houston Ship Channel	Census Tract 343	Census Tract 313	Census Tract 301	Census Tract 439
Mortality	Highest	Lowest	3rd Highest	3rd Highest	3rd Highest	3rd Highest
Number of Suspended Particulate Matter	Largest	Largest	3rd Largest	3rd Largest	2nd Largest	3rd Largest
Weight of Suspended Particulate Matter	Highest	2nd Highest	2nd Lowest	2nd Highest	2nd Highest	2nd Lowest
Socio-economic Status	Low	Medium Low	Medium High	Medium High	Medium Low	High

## VI. Conclusion

The regression analysis has been applied to the suspended particulate size distribution data measured. The high coefficient of correlation value (0.897 - 0.999) and the low value of standard error of estimate (0.037 - 0.350) indicated that it was valid to use the power function to describe the suspended particle size distributions. Also, the intercept, slope, and the percentage of particles in 0.3 - 0.7  $\mu\text{m}$  size range characterize the four stations which represent commercial, semirural, residential, and industrial areas in Houston, and mark the seasonal variation as well.

Most of the time, the distribution patterns for 0.3 - 0.7  $\mu\text{m}$ , 0.7 - 1.4  $\mu\text{m}$ , 1.4 - 3.0  $\mu\text{m}$ , and 3.0 - 10.0  $\mu\text{m}$  size range particles were all different. Analyses of the particle sources and meteorology data in Houston may explain the different distribution pattern of suspended particulate matters with different size ranges. Based on the meteorological data, it could now be concluded that the isopleth maps of size (0.3 - 0.7 $\mu\text{m}$ ) and mass distribution of suspended particulate matter were essentially the same when the wind speed was 5 or less knots, and each distribution changed differently when the wind speed increased to more than 5 knots.

The mortality from asthma, bronchitis, and emphysema associated quite well with suspended particulate size and mass distribution, and better with size distribution than with most distribution. The socio-economic status most likely does not play a decisive role here. The pneumonia mortality in Houston was mostly linked to a lower socio-economic status, a high level of suspended particulate size and mass

distribution with more emphasis on a lower socioeconomic status.

The high tuberculosis prevalence was most observed in low socioeconomic status area, and the high pollution level of suspended particulate matter might well aggravate the situation. The tuberculosis mortality had no socioeconomic significance but was worse in the area where the suspended particulate pollution was high.

The suspended particulate size distribution measurement should be extended to other areas with different topography over a long period of time in order to confirm and better define the above finding. The morbidity data from frequency of outpatient visits, hospital admission, and emergency clinic visits should be collected in order to see the difference in mortality and morbidity. To eliminate the inherited bias in the above methods for the collecting morbidity data, statistical sampling among the population may be employed. The correlation of areal based data should be conducted mathematically. Visual judgements of association were employed in this study due to a lack of continuing funding.

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Appendix 1. The Route Taken to Collect Suspended Particulate Size Distribution Data in Houston

Station	Distance from Last Station (Mile)	Time Taken from Last Station (Minute)	Route Taken from Last Station
SPH	0.0	0.0	Starting place, SPH (School of Public Health, Univ. of Texas at Houston).
7	0.7	4	On W. Holcombe Blvd. going east, turn left on N. MacGregor Rd., on N. MacGregor Rd. going northeast, on 1115 N. MacGregor Rd.
8	3.8	13	On N. MacGregor Rd. going southwest, turn right on W. Holcombe Blvd., on W. Holcombe Blvd. going west, then street name changes to Bellaire Blvd., turn left on Stella Link Rd., on Stella Link Rd. going south, turn right on Aberdeen St., on Aberdeen St. going east, on 3838 Aberdeen Street
9	4.7	15	On Aberdeen St. going west, turn right on Stella Link Rd., on Stella Link Rd. going north, turn left on Bellaire Blvd., on Bellaire Blvd. going west, turn right on Bintiff Rd., on 6902 Bellaire Blvd.
10	6.5	18	On Bintiff Rd. going south, turn right Bellaire Blvd., on Bellaire Blvd. going west, enter Southwest Freeway (U.S. 59 N.) going northeast, exit on Weslayan Rd., on Weslayan Rd. going north, turn right on W. Alabama St., on W. Alabama St. going east, on 3735 W. Alabama St.
11	9.5	20	On W. Alabama St. going west, turn right on Weslayan Rd., on Weslayan Rd. going north, turn left on Westheimer Rd., on Westheimer Rd. going west, enter Interstate 610 West Loop going north, exit on U.S. 290 west, exit on Northwest Freeway, on Northwest Fwy. going northwest, turn left on W.

Station	Distance from Last Station (Mile)	Time Taken from Last Station (Minute)	Route Taken from Last Station
11			43rd St., on W. 43rd St. going west, turn right on Lang St., on Lang St. going north, turn left on Malibu St., on Malibut St. going west, on 4420 Bingle Rd.
12	8.6	21	On Malibu St. going west, turn right on Bingle Rd., on Bingle Rd. going north, turn right on Pinemont Rd., on Pinemount going east, turn left on North Shepherd Dr., on North Shepherd Dr. going north, turn right on Tidwell Rd., on Tidwell Rd. going east, turn left on Airline Rd., on Airline Rd. going north, turn right on Sunnyside St., on Sunnyside St. going east, corner of Sunnyside St. and Fulton St., on 10413 Fulton St.
13	8.5	28	On Fulton St. going southeast, turn left on Tidwell Rd. on Tidwell Rd. going east, turn left on E. Hardy Rd., on E. Hardy Rd. going north, turn right on Tidwell Rd., on Tidwell Rd. going east, turn right on N. Wayside St. (Settegast St.), on N. Wayside St. going south, turn left on Dockat St., on 7330 N. Wayside St.
16	9.5	15	On N. Wayside St. going south, enter Interstate 610 North Loop going southeast, enter Interstate 10 East, exit on Market and Uvlade Streets, on Uvalde St. going north, turn left on Vicksburg St., on 13349 Vicksburg St.
14	8.0	20	On Vicksburg St. going south, enter Interstate 10 West, exit on Kress St., on Kress St. going north, on corner of Kress St. and Lyons St.
2	3.4	10	On Kress St. going south, enter Interstate 10 West, exit on San Jacinto St., on N. San Jacinto St. going south, on 811 N. San Jacinto St.

Station	Distance from Last Station (Mile)	Time Taken from Last Station (Minute)	Route Taken from Last Station
P1	16.0	23	On N. San Jacinto St. going north, enter Interstate 10 West, enter Interstate 45 South going first south and then southwest, enter Texas 225 East, exit on Richey St., on Richey St. going north, turn right on Shaw St., on Shaw St. going east, on the corner of Shaw St. and Walter St.
3	5.0	10	On Walter St. going south, enter Texas 225 West, exit on Allen-Genoa Rd., on Allen-Genoa Rd. going northwest, turn left on Lawndale St., on Lawndale St. going northwest, turn right on San Antonio, on 824 San Antonio St.
4	11.2	21	On San Antonio St. going south, turn right on Lawndale St., on Lawndale going west, turn left on Evergreen St., on Evergreen St. going south, turn right on Woodridge St. on Woodridge St. going southwest, enter Interstate 45 South going southwest, exit on Almeda-Genoa Rd., through clover leaf shaped road to Frey St., on Frey St. going north, turn left on Hartsook St., on Hartsook St. going west, on 10343 Hartsook St.
5	10.5	20	On Hartsook St. going east, turn right on Frey St., on Frey St. going south, turn right on Almeda-Genoa Rd., on Almeda-Genoa Rd. going west, turn left on Telephone Rd., on Telephone Rd. going south, turn right on Almeda-Genoa Rd., on Almeda-Genoa Rd. going west, turn right on Cullen Rd., on Cullen Rd. going north, on 11212 Cullen Rd.
SPH	8.3	18	On Cullen Rd. going north, enter Interstate 610 North Loop going west, exit on Fannin St., on Fannin St. going north, turn right on W. Holcombe Blvd., on W. Holcombe Blvd. going east, S.P.H.
Total	114.2	262	

Appendix 2. Suspended Particulate Size Distribution Raw Data in Houston on August 23, 25, and 28, 1972  
 Number of Particles Per ft<sup>3</sup>

Station	Date	Time	Temp. (°F)	Humidity (%)	0.3-0.5 μm	0.5-0.7 μm	0.7-1.4 μm	1.4-3.0 μm	3.0-10 μm
P1	8/23	1552	78/90	87	361,980	(220,000)	90,490	39,950	(6,000)
	----	----	---	--	350,620	(200,000)	103,290	45,150	(5,800)
	8/25	1426	78/85	78	65,160	45,700	35,410	34,560	2,320
	----	----	---	--	81,280	60,010	45,730	33,410	2,340
	8/28	1426	82/97	73	108,450	49,410	28,130	19,590	(2,500)
	----	----	---	--	104,400	43,490	25,340	19,620	(2,000)
2	8/23	1358	78/90	58	3,920,700	(1,500,000)	239,900	117,200	(17,000)
	----	----	---	--	3,757,900	(1,400,000)	214,700	135,700	(15,000)
	8/25	1359	79/85	76	95,180	53,100	37,510	35,360	4,150
	----	----	---	--	79,430	50,000	44,650	38,330	3,410
	8/28	1352	80/96	50	144,950	63,940	37,200	34,480	(5,000)
	----	----	---	--	175,850	76,630	39,900	39,580	(5,200)
3	8/23	1619	74/83	66	388,690	(220,000)	134,730	57,220	(6,500)
	----	----	---	--	396,280	(200,000)	80,550	46,740	(7,000)
	8/25	1515	78/84	76	94,210	57,990	45,800	40,440	3,530
	----	----	---	--	127,150	95,190	52,440	44,020	5,660
	8/28	1447	79/93	54	322,920	77,410	33,560	30,240	(5,000)
	----	----	---	--	386,450	183,690	92,110	45,140	(6,000)
4	8/25	1550	81/92	62	60,920	44,130	43,890	57,950	4,370
	----	----	---	--	67,650	45,700	40,460	54,300	4,240
	8/28	1526	82/98	50	131,090	49,580	22,030	15,990	(2,500)
	----	----	---	--	115,140	46,220	22,220	15,410	(2,200)

Station	Date	Time	Temp. (°F)	Humidity (%)	0.3-0.5 μm	0.5-0.7 μm	0.7-1.4 μm	1.4-3.0 μm	3.0-10 μm
5	8/25	1622	84/95	64	58,390	41,190	36,220	41,930	3,040
	—	—	—	—	43,850	37,150	36,890	46,590	4,040
	8/28	1602	80/95	52	200,810	65,990	28,250	22,280	(2,000)
	—	—	—	—	175,380	57,320	24,750	23,320	(4,000)
6	8/23	1648	76/85	66	244,120	(120,000)	45,740	17,370	(3,000)
	—	—	—	—	266,980	(130,000)	46,840	19,930	(3,500)
7	8/23	0952	79/87	70	201,020	(120,000)	51,450	24,100	(4,200)
	—	—	—	—	179,500	(120,000)	44,770	17,980	(4,000)
	8/23	1712	77/87	64	316,790	(190,000)	64,000	26,530	(6,800)
	—	—	—	—	376,800	(200,000)	66,510	26,030	(6,000)
	8/25	0912	78/85	73	109,130	58,890	56,520	59,500	5,190
	—	—	—	—	111,780	59,260	53,540	64,440	5,620
	8/25	1657	81/94	57	74,750	60,780	58,870	65,610	5,160
	—	—	—	—	71,980	58,080	44,080	54,450	4,760
	8/28	0927	79/88	67	170,400	70,110	49,470	34,670	(4,000)
	—	—	—	—	164,790	65,760	51,510	38,500	(4,000)
	8/28	1634	81/96	53	331,220	116,010	45,070	30,480	(6,000)
	—	—	—	—	284,450	98,840	51,360	33,130	(5,000)
8	8/23	1022	78/86	70	108,580	(70,000)	21,900	19,800	(3,500)
	—	—	—	—	105,050	(68,000)	21,400	19,560	(3,200)
	8/25	0942	81/89	71	47,680	22,650	42,870	46,930	4,790
	—	—	—	—	32,660	29,830	36,720	45,230	3,520

Station	Date	Time	Temp. (°F)	Humidity (%)	0.3-0.5 $\mu\text{m}$	0.5-0.7 $\mu\text{m}$	0.7-1.4 $\mu\text{m}$	1.4-3.0 $\mu\text{m}$	3.0-10 $\mu\text{m}$
8	8/28	0955	79/90	58	98,220	36,140	23,570	14,150	(3,000)
	---	---	---	--	100,920	36,520	21,030	14,810	(3,000)
9	8/23	1050	74/86	57	55,490	(35,000)	13,090	10,890	(2,000)
	---	---	---	--	69,500	(45,000)	15,290	9,920	(2,000)
	8/25	1007	82/90	70	41,650	32,850	39,410	53,110	4,940
	---	---	---	--	36,690	38,900	37,400	53,870	4,520
	8/28	1022	79/90	62	56,810	20,800	11,830	8,720	(3,000)
	---	---	---	--	56,570	20,000	11,620	9,480	(3,000)
10	8/23	1116	80/87	74	191,700	(120,000)	33,890	23,010	(3,500)
	---	---	---	--	146,730	(100,000)	35,380	25,730	(5,000)
	8/25	1032	81/91	65	33,180	39,510	39,530	45,060	4,510
	---	---	---	--	38,540	38,820	37,540	44,300	4,600
	8/28	1058	80/94	54	84,730	35,850	16,070	10,180	(2,500)
	---	---	---	--	86,530	36,420	14,900	11,030	(3,000)
11	8/23	1154	78/90	58	57,370	(40,000)	13,530	15,060	(2,000)
	---	---	---	--	60,130	(42,000)	13,640	15,390	(2,000)
	8/25	1105	81/92	62	33,070	38,640	36,930	39,730	4,130
	---	---	---	--	34,110	40,300	37,230	40,520	4,250
	8/28	1129	80/94	54	97,540	43,250	24,540	18,070	(5,000)
	---	---	---	--	103,220	42,580	20,860	19,840	(5,500)
12	8/23	1227	86/94	54	92,750	(65,000)	26,570	15,530	(3,000)
	---	---	---	--	100,950	(74,000)	22,620	15,090	(4,000)

Station	Date	Time	Temp. (°F)	Humidity (%)	0.3-0.5 $\mu\text{m}$	0.5-0.7 $\mu\text{m}$	0.7-1.4 $\mu\text{m}$	1.4-3.0 $\mu\text{m}$	3.0-10 $\mu\text{m}$
12	8/25	1142	81/94	57	40,260	41,110	32,720	49,980	4,290
	—	—	—	—	56,270	41,740	34,930	56,120	4,840
	8/28	1158	81/96	53	122,830	45,130	21,560	26,640	(4,400)
	—	—	—	—	120,110	53,170	24,490	27,550	(5,000)
13	8/23	1320	80/87	74	84,320	(56,000)	17,790	11,630	(3,000)
	—	—	—	--	102,850	(70,000)	17,590	12,030	(3,500)
	8/25	1231	77/85	70	162,780	127,850	90,980	98,310	4,190
	—	—	—	—	150,160	138,890	93,400	91,730	4,200
14	8/28	1238	84/98	55	111,190	40,120	21,140	28,670	(4,000)
	—	—	—	—	115,230	41,870	20,990	27,860	(4,000)
	8/23	1420	77/85	70	711,900	(360,000)	172,300	120,600	(35,000)
	—	—	—	—	744,340	(500,000)	195,050	205,060	(70,000)
15	8/25	1336	78/82	84	138,320	71,100	56,670	64,880	7,580
	—	—	—	—	160,230	85,350	61,000	61,320	6,060
	8/28	1333	82/97	53	102,510	63,830	29,040	19,780	(4,300)
	—	—	—	—	110,020	52,790	28,800	20,290	(4,000)
16	8/23	1454	75/82	73	358,570	(220,000)	67,910	42,370	(5,000)
	—	—	—	—	285,420	(200,000)	66,320	49,940	(5,000)
16	8/23	1515	74/80	74	266,990	(180,000)	62,540	43,380	(5,000)
	—	—	—	—	259,370	(160,000)	62,440	40,180	(5,000)
	8/25	1305	78/83	80	764,670	441,950	231,660	183,230	6,780
—	—	—	—	—	979,800	585,240	287,270	230,150	6,280



Appendix 3. Suspended Particulate Size Distribution Raw Data in Houston on October 4, 5, and 6, 1972  
 Number of Particles per ft<sup>3</sup>

Station	Date	Time	Temp. (°F)	Humidity (%)	0.3-0.5 μm	0.5-0.7 μm	0.7-1.4 μm	1.4-3.0 μm	3.0-10.0 μm
2	10/4	10:11	67/78	56	272,070	82,780	37,510	23,370	3,710
					263,620	72,460	28,280	12,880	2,640
	10/4	13:08	72/84	56	367,370	103,740	34,200	26,640	2,870
					272,670	90,290	30,910	18,960	2,410
	10/5	11:42	76/84	69	857,480	492,400	375,350	168,400	4,490
					927,120	652,220	612,030	424,030	3,660
	10/5	14:40	76/90	52	487,440	282,070	117,530	47,810	2,160
					400,120	218,040	101,080	74,030	13,010
	10/6	11:45	75/85	62	216,320	89,810	42,060	16,380	1,920
					340,580	143,420	43,630	22,390	4,340
	10/6	14:12	76/90	52	128,480	53,320	25,960	12,320	1,100
					129,740	45,090	16,720	9,420	1,020
4	10/4	11:51	75/88	53	482,680	142,710	54,460	15,570	1,150
					586,210	199,290	69,330	25,720	1,410
	10/4	14:30	77/91	52	160,390	45,630	15,400	6,310	1,040
					153,860	38,800	12,770	6,120	670
	10/5	10:13	77/81	83	982,200	473,850	346,100	115,720	2,470
					573,270	299,240	201,530	78,130	1,980
	10/5	13:25	77/90	55	209,560	76,740	26,250	7,430	1,320
					176,630	52,510	18,480	11,090	980

Station	Date	Time	Temp. (°F)	Humidity (%)	0.3-0.5 μm	0.5-0.7 μm	0.7-1.4 μm	1.4-3.0 μm	3.0-10.0 μm
4	10/6	12:58	76/79	87	141,900	47,190	19,400	8,750	1,290
					147,710	930	17,820	9,710	1,500
	10/6	15:37	76/93	46	130,930	46,180	16,760	8,740	870
					144,090	50,520	16,150	8,420	950
8	10/4	9:20	67/76	62	595,260	188,310	90,140	41,220	2,710
					595,730	206,230	93,610	43,550	3,120
	10/4	12:33	73/85	61	439,580	143,260	53,190	17,720	1,410
					413,470	134,480	51,090	21,580	2,070
	10/5	10:50	78/85	73	1,472,760	918,800	588,190	196,090	4,840
					1,696,070	1,413,420	706,220	344,270	5,060
	10/5	14:03	77/91	52	186,730	60,850	21,560	8,990	1,140
					165,380	62,220	20,420	8,940	1,020
	10/6	11:07	76/85	71	182,480	52,360	25,460	10,960	1,310
					159,850	46,060	23,090	11,730	1,200
	10/6	13:35	76/93	50	110,050	41,610	17,230	8,600	990
					109,840	42,920	16,540	9,660	1,560
16	10/4	10:42	71/81	58	285,030	77,280	28,370	11,580	860
					316,310	85,110	28,320	12,800	1,010
	10/4	13:37	74/84	62	211,200	65,790	22,720	11,090	1,150
					232,410	66,060	19,780	10,010	1,280



Appendix 4. Suspended Particulate Size Distribution Raw Data in Houston on November 29,  
December 1 and 4, 1972.

Number of Particles per ft<sup>3</sup>

Station	Date	Time	Temp. (°F)	Humidity (%)	0.3-0.5 μm	0.5-0.7 μm	0.7-1.4 μm	1.4-3.0 μm	3.0-10.0 μm
P1	11/29	1413	49/57	55	155,070	62,110	30,940	10,520	1,260
					161,420	54,250	22,750	11,140	1,140
12/1	1019	49/56		60	334,140	99,760	28,850	6,850	550
					326,930	97,660	23,230	6,270	1,020
12/4	1223	52/56		76	345,000	160,750	96,050	28,260	1,070
					362,190	173,410	94,900	53,790	2,860
2	11/29	1335	48/56	55	218,760	102,880	30,880	10,180	1,280
					280,250	142,450	45,540	18,270	2,270
12/1	1105	51/61		49	181,390	60,150	14,760	12,970	5,270
					231,030	83,640	23,340	12,690	1,990
12/4	1332	53/57		77	494,670	279,130	138,790	111,590	3,360
					500,270	250,230	129,190	10,210	1,640
3	11/29	1437	48/56	55	183,480	84,740	35,630	13,780	2,340
					293,140	114,340	41,130	17,290	2,170
12/1	1033	52/60		58	165,510	51,260	15,840	5,490	1,360
					222,440	67,670	26,130	7,200	880
12/4	1301	52/56		76	516,970	257,360	137,260	35,810	1,330
					539,950	261,060	141,530	39,880	1,430
4	11/29	0925	48/54	64	342,540	100,010	33,710	7,720	820
					395,680	105,980	33,850	7,600	780

Station	Date	Time	Temp, (°F)	Humidity (%)	0.3-0.5 μm	0.5-0.7 μm	0.7-1.4 μm	1.4-3.0 μm	3.0-10.0 μm
4	12/1	1518	49/56	60	277,640	106,580	44,570	16,920	2,050
					319,510	141,600	57,540	20,520	2,040
12/4	1155	53/56	82		633,710	395,080	296,070	109,990	1,710
					596,550	321,760	228,420	61,440	2,350
5	11/29	1602	51/59	57	119,490	46,230	15,410	11,130	1,910
					147,420	53,010	17,880	7,390	880
12/1	0847	46/51	68		394,210	126,290	32,830	7,880	920
					347,010	96,590	33,090	12,120	1,940
12/4	1123	52/57	71		417,050	213,730	133,300	31,680	1,480
					466,060	248,430	155,190	40,626	1,200
7	11/29	0846	45/49	73	156,800	60,690	33,090	16,530	1,330
					155,500	99,560	34,430	16,390	1,450
12/1	1547	53/64	47		110,970	36,930	14,660	6,740	640
					115,320	49,990	12,300	5,900	550
12/4	1055	51/55	76		582,580	252,810	171,640	64,590	1,680
					576,040	244,720	163,300	55,860	1,570
8	11/29	0917	45/51	62	166,970	72,210	45,520	19,730	1,050
					166,180	65,520	35,920	13,960	1,130
12/1	1522	53/65	44		116,950	37,970	10,920	3,370	390
					130,790	43,480	10,060	4,080	390

Station	Date	Time	Temp. (°F)	Humidity (%)	0.3-0.5 μm	0.5-0.7 μm	0.7-1.4 μm	1.4-3.0 μm	3.0-10.0 μm
8	12/4	1030	51/55	76	452,730	231,990	176,980	82,670	1,590
					523,380	228,130	176,020	104,080	1,550
9	11/29	0943	48/52	75	142,600	62,140	38,780	13,130	1,060
					161,470	67,610	39,360	14,360	850
12/1	12/1	1419	52/64	43	105,720	34,110	7,620	3,180	360
					114,600	43,740	8,530	3,690	340
12/4	12/4	1658	50/53	81	459,240	231,470	135,320	34,320	980
					507,910	256,280	146,950	49,330	1,620
10	11/29	1010	45/51	62	131,050	61,590	30,140	8,710	980
					157,490	68,560	33,910	9,470	1,060
12/1	12/1	1424	55/67	45	219,490	79,180	15,630	5,180	470
					181,070	69,500	14,740	5,340	530
12/4	12/4	1626	50/54	76	456,430	259,000	143,260	37,610	1,230
					489,300	270,060	153,990	45,580	1,430
11	11/29	1042	46/53	58	74,530	26,940	12,550	6,590	650
					85,000	28,790	12,830	6,770	630
12/1	12/1	1353	51/63	42	188,460	63,370	16,820	5,670	640
					218,370	70,590	16,320	6,060	570
12/4	12/4	1557	49/52	81	409,900	221,280	117,150	32,670	1,020
					450,250	220,050	125,810	45,210	1,300

Station	Date	Time	Temp. (°F)	Humidity (%)	0.3-0.5 μm	0.5-0.7 μm	0.7-1.4 μm	1.4-3.0 μm	3.0-10.0 μm
12	11/29	1113	48/55	59	79,630	30,530	10,960	3,450	350
					77,630	27,010	12,510	4,530	370
	12/1	1314	53/66	40	121,620	40,970	9,620	4,710	700
					134,590	40,790	8,330	4,700	560
13	12/4	1524	51/56	71	305,160	175,680	73,750	12,590	2,180
					345,450	167,370	69,220	14,620	980
	12/1	1210	49/56	60	66,630	27,040	11,620	3,200	360
					65,410	28,660	11,170	2,970	330
14	12/4	1243	52/64	43	118,210	40,460	10,510	4,970	600
					111,940	39,590	11,300	6,000	680
	12/4	1444	51/54	82	388,800	202,290	91,790	22,710	610
					361,510	203,040	89,670	22,810	920
15	11/29	1313	48/57	50	91,490	60,040	15,250	3,810	570
					101,800	36,510	11,000	3,420	310
	12/1	1125	50/66	48	143,300	53,710	11,350	4,650	770
					130,610	41,030	10,180	5,630	720
16	12/4	1352	52/56	76	549,430	251,590	120,680	29,400	1,310
					630,530	384,170	136,540	31,410	1,100
	11/29	1245	49/56	60	57,670	25,490	10,320	3,130	300
					66,010	26,720	8,050	2,930	420



Appendix 5. Suspended Particulate Size Distribution Raw Data<sub>3</sub> in Houston on February 5, 6, and 15, 1973  
 Number of Particles per ft<sup>3</sup>

Station	Date	Time	Temp. (°F)	Humidity (%)	0.3-0.5 μm	0.5-0.7 μm	0.7-1.4 μm	1.4-3.0 μm	3.0-10.0 μm
P1	2/5/73	1545	66/74	65	43,850	34,740	19,920	14,480	2,090
					40,360	45,490	22,510	15,890	2,100
	2/6/73	1040	69/75	74	140,310	81,770	41,080	18,840	3,320
					87,630	57,190	28,040	13,630	2,690
	2/15/73	1630	50/59	52	74,270	48,560	18,250	19,170	1,490
					193,820	158,550	48,630	18,920	1,410
2	2/5/73	1443	66/76	59	47,960	42,040	16,870	12,620	2,560
					51,020	48,700	19,680	15,880	2,540
	2/6/73	1200	68/73	78	119,630	78,240	38,020	19,280	3,540
					126,060	70,040	32,570	20,830	3,930
	2/15/73	1000	41/47	59	139,510	41,900	13,730	7,770	1,310
					152,090	52,540	15,510	5,160	590
3	2/5/73	1523	65/78	49	45,240	38,050	19,420	17,670	2,360
					31,370	32,530	17,900	13,670	2,120
	2/6/73	1113	69/75	74	109,590	74,280	40,490	22,370	3,510
					80,460	65,750	36,310	22,270	3,330
	2/15/73	1706	47/58	41	86,850	27,650	6,940	4,210	1,310
					74,670	22,500	5,230	6,530	630
4	2/5/73	1625	66/76	59	38,570	31,810	19,760	11,340	1,860
					35,440	29,170	19,750	12,050	2,240

Station	Date	Time	Temp. (°F)	Humidity (%)	0.3-0.5 μm	0.5-0.7 μm	0.7-1.4 μm	1.4-3.0 μm	3.0-10.0 μm
4	2/6/73	1003	68/74	74	251,630	195,140	153,010	101,050	3,600
					197,310	165,100	127,670	69,770	3,970
	2/15/73	1600	52/65	39	80,450	32,640	8,190	2,820	280
					76,140	29,220	6,380	2,950	380
x5	2/5/73	1705	65/78	49	32,890	29,370	22,860	17,510	2,420
	2/6/73	0917	65/75	58	175,290	93,570	67,550	45,750	3,350
					193,100	116,970	81,020	66,120	7,000
	2/15/73	1523	49/59	47	106,920	62,980	6,360	2,980	290
					72,240	26,870	6,440	2,470	370
7	2/5/73	0934	64/68	80	94,890	53,130	40,040	22,140	3,200
					66,640	41,570	34,710	19,830	3,590
	2/6/73	1650	68/72	82	142,570	61,820	31,020	20,900	4,070
					119,120	65,240	28,480	27,830	3,160
	2/15/73	1455	51/65	35	91,540	29,550	6,680	2,700	290
					85,990	39,430	9,750	3,950	390
8	2/5/73	1016	66/70	81	33,610	30,740	29,310	21,800	2,930
					32,640	32,020	28,530	21,450	3,380
	2/6/73	1621	69/77	67	416,460	372,650	220,220	71,070	3,850
					489,680	360,760	175,090	102,840	4,370
	2/15/73	1426	53/66	40	89,180	31,610	4,970	2,680	260

Station	Date	Time	Temp. (°F)	Humidity (%)	0.3-0.5 μm	0.5-0.7 μm	0.7-1.4 μm	1.4-3.0 μm	3.0-10.0 μm
8	2/15/73	1426	53/66	40	79,680	25,020	4,850	2,540	230
9	2/5/73	1042	66/72		38,370	34,370	29,680	19,820	3,580
					31,020	32,230	36,170	20,780	3,240
	2/6/73	1520	67/75	73	64,260	30,680	12,820	12,020	2,060
					60,260	30,720	16,080	17,720	4,310
	2/15/73	1354	49/61	40	68,500	22,260	6,310	1,930	210
					71,790	30,430	6,720	1,720	180
10	2/5/73	1108	65/70	77	39,440	38,100	26,240	13,030	2,390
					36,010	31,620	25,930	18,030	3,830
	2/6/73	1554	68/72	82	289,040	252,200	184,900	98,650	2,490
					310,010	289,520	218,860	138,810	3,020
	2/15/73	1327	48/58	46	118,570	39,890	5,340	3,580	430
					121,640	34,090	3,890	3,380	400
11	2/5/73	1140	67/74	69	34,690	32,510	23,480	11,810	1,960
					33,610	31,720	24,060	18,790	2,650
	2/6/73	1458	68/77	63	80,900	52,040	30,510	20,840	3,610
					125,870	54,370	26,460	20,990	3,620
	2/15/73	1250	47/57	45	77,240	23,820	4,370	1,520	320
					81,750	23,660	5,040	1,640	120
12	2/5/73	1215	66/74	62	38,990	32,690	20,990	14,050	2,170

Station	Date	Time	Temp. (°F)	Humidity (%)	0.3-0.5 $\mu\text{m}$	0.5-0.7 $\mu\text{m}$	0.7-1.4 $\mu\text{m}$	1.4-3.0 $\mu\text{m}$	3.0-10.0 $\mu\text{m}$
12	2/5/73	1215	66/74	62	37,880	32,640	21,740	17,880	2,700
	2/6/73	1357	69/76	70	145,330	81,890	31,760	15,890	3,040
					128,850	74,150	28,340	16,270	3,320
	2/15/73	1216	49/58	51	77,570	23,870	7,430	1,960	190
					76,110	22,790	6,240	4,590	430
13	2/5/73	1314	68/80	54	52,640	44,870	25,250	20,180	1,600
					52,730	43,050	19,010	12,390	1,690
	2/6/73	1324	67/76	62	256,620	109,620	50,240	21,710	3,590
					200,140	97,750	43,430	24,510	4,120
	2/15/73	1134	45/54	48	86,040	19,680	6,350	1,510	770
					65,700	21,590	10,670	5,760	220
14	2/5/73	1419	66/77	56	60,480	49,460	28,740	15,670	2,070
					58,730	38,830	22,700	17,430	2,880
	2/6/73	1224	68/74	74	182,840	175,170	125,590	59,540	5,370
					248,870	153,810	93,400	52,160	4,520
	2/15/73	1028	42/48	60	122,620	50,110	8,080	3,000	310
					107,570	34,600	8,110	2,590	300
16	2/5/73	1347	68/79	57	101,210	71,320	27,350	24,320	2,210
					67,080	54,330	20,620	17,490	2,290
	2/6/73	1255	66/73	69	1196,540	747,060	422,680	289,170	3,460

Station	Date	Time	Temp. (°F)	Humidity (%)	0.3-0.5 μm	0.5-0.7 μm	0.7-1.4 μm	1.4-3.0 μm	3.0-10.0 μm
16	2/6/73	1255	66/73	69	1,275,440	836,940	465,580	321,110	3,680
	2/15/73	1059	48/56	55	91,760	20,490	6,140	2,230	520
					88,170	25,390	9,620	3,430	190

APPENDIX 6Asthma, Bronchitis, Emphysema,  
Pneumonia, and Tuberculosis

Asthma is generally caused by an allergy and characterized by a narrowing of air passages which causes great difficulty in breathing. The symptoms are often temporary but recurrent, and disappear when the allergen disappears from the air the patient breaths.

Bronchitis means a long-lasting irritation of the mucous secretion in the bronchial tubes and hence a blockage of these air passages. It is manifested by a paroxysmal coughing and excess sputum. This disease can last for years.

Emphysema has been noted to be the most important chronic breathing disorder. The chief symptom is shortness of breath, excess sputum and coughing. It may or may not be complicated by infectious agents. Unlike bronchitis the main difference is the permanent destructive changes of the areolar wall. The treatment available can only ease the symptoms and not restore the areolar tissues.

Lobar pneumonia may be caused by many different microorganisms but mostly is caused by Diplococcus pneumoniae. Acute pneumococcal lobar pneumonia is a severe illness with sudden onset, chills, fever, cough, chest pain, dyspnea and leucocytosis. Treatment is generally successful with chmotherapeutic agents except for viral or pneumocystis pneumonia. With the discovery of antibiotics, the disease is now easily treated and controlled where it used to be fatal.

Tuberculosis is a chronic bacterial disease and an important cause of death in many parts of the world. The Mycobacterium tuberculosis infects the lung and causes lesions which commonly become inactive leaving only pulmonary or tracheobronchial lymph node calcifications. The disease may again become active and progress to more extensive lung involvement and in severe cases involvement of other organs. Symptoms are often absent until advanced stages and include cough, fatigue, fever, weight loss, and chest pain. Treatment includes long term antimicrobial drug therapy.

Prevalence of this infection increases with age. It is usually higher in cities than in rural areas. There has been a rapid decline of the disease in recent decades due to improved methods to control the disease.

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